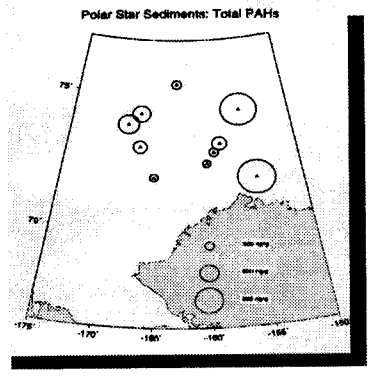
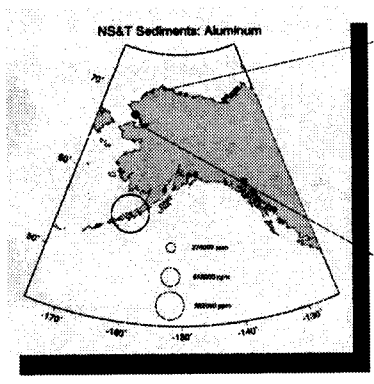
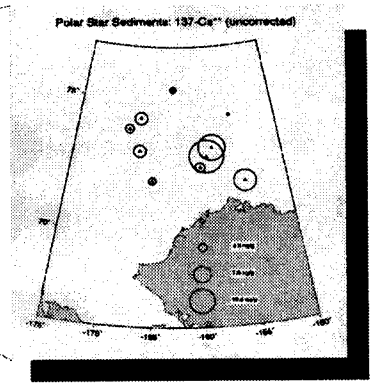
NOAA Technical Memorandum NOS ORCA 108

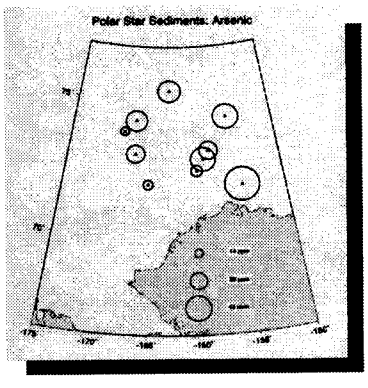
National Status and Trends Program
for Marine Environmental Quality

Contaminants in the Sediments and Biota of the Western Beaufort Sea









Silver Spring, Maryland
December 1997

US Department of Commerce

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Coastal Monitoring and Bioeffects Assessment Division
Office of Ocean Resources Conservation and Assessment
National Ocean Service

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Notice

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CONTAMINANTS IN SEDIMENTS AND BIOTA FROM THE WESTERN BEAUFORT SEA

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Abstract

Beaufort Sea surficial sediments and benthic biota samples were analyzed for a suite of: trace metals; organochlorine contaminants, including pesticides and polychlorinated biphenyls (PCBs); polyaromatic hydrocarbons (PAHs); and radionuclides. The samples were collected in 1993 at 11 sites during a cruise of the Coast Guard icebreaker "Polar Star."

Trace metals were only analyzed in the sediments. In the samples, only arsenic displayed high concentrations (up to 58 ppm grainsize-corrected value) that may be related to the presence of ore deposits in the area.

Most of the sediment samples were devoid of detectable amounts of organochlorine contaminants. Only lindane, total DDTs (tDDT), and total PCBs (tPCBs) were consistently found in measurable amounts. Lindane concentrations ranged from below detection to 0.26 ng/g dry weight (detected in 6 out of 10 samples), tDDTs ranged from undetected to 0.78 ng/g (detected in 8 out of 10 samples), and tPCBs ranged from 0.54 to 2.51 ng/g dry weight (detected in all samples, the highest values being measured at stations located near the coast). These concentrations are much lower than the values believed to cause biological effects (Long and Morgan, 1990; Long *et al.*, 1995).

Organochlorine contaminants were consistently found in marine invertebrates as well as in fish collected during the Polar Star cruise. Total PCBs were generally more concentrated in invertebrates than in fish (12.23 ng/g dry weight versus 7.97 ng/g), whereas tDDTs and other pesticides were higher in fish than in invertebrates (3.22 ng/g versus 0.74 ng/g and 19.08 ng/g versus 9.46 ng/g, respectively). Sea urchins collected from a shallow site, G1, displayed the highest concentrations in

tPCBs (30.93 ng/g dry weight), and hermit crabs from the same site were enriched in tPesticides (mostly dieldrin = 12.8 ng/g). High concentrations of hexachlorobenzene (~13 ng/g) were also found in *Macoma calcarea* samples collected at site B4. Organochlorine concentrations were generally lower than those found in other parts of the United States.

Concentrations of resolved polycyclic aromatic hydrocarbons in the sediments ranged from ~160 to ~1100 ng/g dry weight. They had a large contribution of total naphthalenes and total phenanthrenes/anthracenes, which constituted about 36% and 35% of the total PAHs (grain size corrected values), respectively. These values are in general agreement with earlier data obtained in shallow waters along the Beaufort Sea coast, except in East Harrison Bay (near the mouth of the Colville River), where much higher concentrations were found during a previous study (mean value ~ 2500 ng/g). Possible sources of PAHs to the region include the outflow from rivers, peat from eroded coastline, oil seeps, Prudhoe Bay oil fields, diagenesis, and long-range atmospheric transport. Diagnostic ratios do not suggest crude oil as the main source of PAHs in the western Beaufort Sea. In the biota, invertebrates (*Macoma calcarea* = 57.32 ng/g) displayed higher concentrations of total PAHs than fish (whole body = 19.91 ng/g), with naphthalene being the largest contributor (~38%).

In the Beaufort Sea samples, ^{137}cesium (Cs) was the only gamma-emitting radionuclide found in significant amounts in sediments and in biota. ^{137}Cs activities ranged from 1 to 12 Bq/kg dry weight in the sediments and from 0.3 to 1 Bq/kg dry weight in benthic biota. In the subsistence biota, the average activities of ^{137}Cs in bowhead whale tissue were about 0.09 Bq/kg in blubber, 0.07 Bq/kg in lungs, and 0.44 Bq/kg in liver. In king eider, ^{137}Cs activity was found to be <0.4 Bq/kg dry weight in muscle and <0. 5 Bq/kg in bones. Extremely low values were recorded for ^{90}strontium (Sr) in all samples. The $^{239\text{-}249}$plutonium (Pu) activity ranged from undetectable to 0.52 Bq/kg dry weight in the sediments and was almost always undetectable in biota samples. The ratio ^{240}Pu/^{239}Pu in the sediments was about 0.17 to 0.24 (mean = 0.19) showing that the plutonium found in the Beaufort Sea samples originated from the global fallout that followed the 1950s nuclear weapons testing. However, ^{137}Cs may have a more complex origin, possibly involving, in addition to global fallout, the fallout from the Chernobyl accident (low ^{90}Sr, high ^{137}Cs) and other sources.

Introduction

For nearly 30 years, the occurrence of contaminants, including radionuclides, has been documented in the Arctic environment (Seymour, 1966; Hanson *et al.*, 1966; Watson *et al.*, 1966). During the past two decades, more information has become available on a wide spectrum of contaminants, including toxic metals, organic compounds, and radionuclides (Barrie *et al.*, 1992; Muir *et al.*, 1992; Aarkrog, 1993; 1995). Contaminants of primary concern are listed in Table 1.

Table 1: CONTAMINANTS OF PRIMARY CONCERN IN THE ARCTIC

*DDT and its metabolites
*Chlorinated pesticides other than DDT (lindane, etc.)
*Organo-metallic compounds, e.g. butyltins
* Polychlorinated biphenyls (PCBs)
*Petroleum contaminants and polycyclic aromatic hydrocarbons (PAHs)
*Toxic metals (arsenic, cadmium, lead, and mercury)
*Acidifying gases (sulfur dioxides, nitrogen oxides, etc.)
*Aerosols and other contaminants in the "Arctic Haze"
*Radionuclides

The published literature (Davis *et al.*, 1991; Futsaeter *et al.*, 1991; Jensen, 1991; Melnikov, 1991; Nenonen, 1991; Paakola, 1991; Hansen *et al.*, 1996) reveals that anthropogenic contaminants are often found in the Arctic in the atmosphere, snowpack, rivers, sediments, and a wide variety of biota ranging from algae to large marine mammals. Recently, concern has increased in the United States and other Arctic countries about the potentially harmful effects of reported releases of radioactive materials to the Arctic Ocean and adjacent seas by past operations of the Former Soviet Union (Yablokov *et al.*, 1993). These included: the dumping of nuclear reactors from ships and nuclear submarines; atmospheric and undersea nuclear testing; blasting for mining and engineering; and widespread discharge of wastes from military operations. In addition, nearly all major Russian rivers that empty into the Arctic Ocean (e.g. the Ob, Yenisey, Lena, and Kolyma) are known to receive large quantities of waste discharges from nuclear weapons factories, electric generating plants, industrial

outfalls, and/or agricultural runoff. It has been suggested that pollution of the Russian Arctic is widespread and may even be catastrophic (Yablokov *et al.*, 1993).

Within the U.S. government, concern regarding such pollution has been reflected in special Congressional hearings; appropriations of funds earmarked to study Arctic radionuclides pollution; numerous discussions and ongoing collaborative efforts among different agencies; and recommendations for environmental research, assessments, and monitoring.

As a result, the Office of Naval Research initiated a multidisciplinary study program, the Arctic Nuclear Waste Assessment Program (ANWAP), to determine the status and fate of pollutants in the Arctic marine system, with emphasis on radioactive wastes originating from the Former Soviet Union. Due to concerns expressed by subsistence users of marine resources along the coasts of Alaska, several research projects were initiated to assess the present level of contamination in Alaskan waters. Additionally, the USCG icebreaker "Polar Star" conducted a cruise in the Beaufort Sea during the summer of 1993.

Purpose of the study

For over a decade, the National Oceanic and Atmospheric Administration's (NOAA) National Status and Trends Program (NS&T) has taken the lead in establishing a quality-controlled data set on the spatial distribution and scales of contamination from radionuclides, trace metals, and organic compounds in sediments and selected biota in coastal waters of the United States. As part of this Program, the present study was undertaken to establish a quality-controlled data set on the spatial distribution and the scale of contamination from a variety of radionuclides and toxic chemicals in the environment and selected faunal samples from the U.S. Arctic in order to :

1) describe the present extent and sources of environmental pollution,
2) establish a baseline to determine temporal trends, and
3) develop strategies to establish a long-term monitoring program.

Sampling and Methods

A) Samples collection

Sampling sites were located in the U.S. territorial waters of the east Chukchi and western Beaufort Seas (Table 2 - Appendix B1). The sampling took place during the summer 1993 cruise of the US Coast Guard icebreaker Polar Star. Bottom-dwelling animals were collected from 3 stations and sediment samples from 10 stations to be analyzed for organic chemicals, metals, and radionuclides. Biological samples were collected with a benthic oyster dredge, and sediment samples with a vanVeen grab.

Table 2: 1993 Sampling Sites in the Western Beaufort Sea

Station	Latitude	Longitude	Depth, m	Sediments	Biota
B1	71: 59.7N	165: 21.2W	34	yes	no
B4	73: 05.8N	166: 59.8W	52	yes	yes
C1	73: 53.8N	168: 29.7W	236	yes	no
C3	74: 18.1N	167: 05.8W	289	yes	no
D1	75: 23.8N	163: 00.3W	2, 050	yes	no
E1	74: 24.0N	155: 43.1W	3, 813	yes	no
E5	73: 13.3N	158: 16.9W	1, 976	yes	no
E7	72: 54.1N	158: 59.2W	113	yes	yes
E12	72: 30.0N	159: 48.0W	40	yes	no
G1	70: 54.1N	160: 10.7W	44	no	yes
G11	71: 54.3N	154: 46.0W	340	yes	no

The samples were placed in pre-cleaned containers and frozen. Packing and storage of the samples followed the normal NS&T protocol (Lauenstein and Cantillo, 1993). Sediment samples to be analyzed for organic compounds were placed in double acid cleaned, high temperature combustion glass jars with Teflon lining lids and those to be analyzed for trace metal in double-acid-cleaned LDPE jars. Biological samples to be analyzed for metals were double-enclosed in plastic Ziploc™ bags, and those to be analyzed for organic compounds were double-wrapped in high-temperature, combustion-cleaned aluminum foil and plastic Ziploc™ bags. Samples for

radionuclide analyses were wrapped in high-temperature, combustion-cleaned aluminum foil and Ziploc™ bags.

The sediments collected at depths greater than 45 m were mostly very fine grained muds mixed with fine sands (Appendices B2-B4). Below a very fluffy oxic layer, the sediments were generally gray and anoxic. The biota included invertebrates (mostly mollusks, crustaceans, and echinoderms but also annelids and sipunculids) and vertebrates (fish: sculpin). Tissues samples from animals harvested for subsistence in 1993 (bowhead whale, bearded seal, and king eider) were provided by personnel from North Slope Borough and the U.S. Fish and Wildlife Service.

B) Analytical methods

The contaminants analyzed in the samples were similar to those analyzed by NOAA's NS&T Program (Lauenstein and Cantillo, 1993; Valette-Silver and Lauenstein, 1995). These include: 4 major elements (Al, Fe, Mn, and Si), 12 trace metals (Sb, As, Cd, Cr, Cu, Pb, Hg, Ni, Se, Ag, Sn, and Zn), 60 organic compounds belonging to 3 groups (chlorinated pesticides, polychlorinated biphenyls [PCBs], and polycyclic aromatic hydrocarbons [PAHs]) and 9 radionuclides (^{241}Am, $^{239+240}$Pu, ^{238}Pu, ^{137}Cs, ^{110}Ag, ^{90}Sr, ^{65}Zn, ^{60}Co, ^{58}Co, and ^{40}K). In addition to the NS&T list, ^{212}Pb and ^{214}Pb were also measured in the samples.

1)Radionuclides

The radionuclides were analyzed (Efurd *et al.*, 1997) at the Los Alamos National Laboratory (LANL). Gamma-emitters radionuclides such as ^{214}Pb, ^{212}Pb, ^{137}Cs, ^{110}Ag, ^{65}Zn, ^{60}Co, ^{58}Co, and ^{40}K, were analyzed by high resolution gamma-ray spectrometry. After γ-counting, the ashen material was dissolved and ^{241}Am, ^{239}Pu, ^{240}Pu, ^{238}Pu, ^{137}Cs and ^{90}Sr were chemically separated. ^{137}Cs and ^{90}Sr were analyzed by β-counting and plutonium and americium were analyzed by α-spectrometry after deposition on a stainless steel disk. The differentiation between the Pu isotopes was performed by thermal ionization mass spectrometry (TIMS).

***Sample Preparation**

The samples were oven-dried at 110°C until constant weights were achieved. The samples were subsequently ashened by placing them in a muffle furnace at 550° C until the organic materials were destroyed. National Institute of Standards and Technology (NIST) Standard Reference Materials (SRM) for Environmental Radioactivity were processed concurrently. The NIST materials were

prepared by the recommended NIST procedure. Robert August, Jr. of the Naval Research Laboratory (NRL) provided an Irish Sea sediment as a blind quality assurance sample.

***Direct Counting of Samples**

Aliquots of approximately 10-25 g of the ashen materials were placed in counting vials and analyzed by high-resolution gamma-ray spectroscopy. Each sample was counted for 3000 minutes. All data are reported as Bq/kg dry weight. Uncertainties are expressed as 1 sigma value derived from counting statistics of both the sample and background. Upper limits are values at which a distinct signal above background can be claimed with 95% confidence. The operating parameters of the counting system were verified with mixed gamma-ray emitting standards traceable to NIST.

The gamma-ray spectra covered the energy range from 50-2000 keV. ^{137}Cs was the only anthropogenic radionuclide detected in the samples by high-resolution gamma-ray spectroscopy although the naturally occurring isotopes ^{40}K, ^{212}Pb, and ^{214}Pb were also detected.

***Chemically Processed Samples**

Aliquots of each sample were dissolved and processed to produce purified cesium (^{137}Cs) and strontium (^{90}Sr) samples. The chemically separated and purified Cs samples were measured by both high-resolution gamma-ray spectroscopy and beta-counting. Sr was measured by beta-counting. Detailed procedures for isolation and chemical purification of radionuclides for sediments and biological samples are provided in Efurd *et al.* (1997).

^{239}Pu and ^{240}Pu emit alpha particles at essentially the same energies and cannot be resolved by alpha-spectroscopy. Therefore, upon completion of alpha-spectroscopy, the plutonium was removed from the counting planchetts, purified, and analyzed by thermal ionization mass spectrometry (TIMS). Mass spectrometry measurement technique (Perrin *et al.*, 1984; Efurd *et al.*, 1991 and 1993; Attrep *et al.*, 1992) measures ^{239}Pu and ^{240}Pu separately and provides an isotopic "fingerprint" that can be used to determine the origin of the plutonium.

***QA/QC**

The analyses performed for this project included high-resolution gamma-spectrometry, alpha and beta-counting analyses, and thermal ionization mass spectrometry (TIMS). The gamma-ray spectrometers were certified with mixed radionuclide gamma-ray standards traceable to NIST. The alpha and beta spectrometers were standardized with NIST certified material. The TIMS were certified

both with NIST and European certified standards. Los Alamos National Laboratory (LANL) runs a minimum 10% of all analyses with matrix-based Quality Assurance (QA) reference materials from the National Institute of Standards and Technology (NIST). NIST SRM 4354 contained 49.9 Bq/kg ^{137}Cs on May 30, 1994. The NIST certified value was decay-corrected using the 30.17 year half-life of ^{137}Cs. NIST SRM 4354 also contains 118 ±15 Bq/kg of ^{60}Co. We measured 114 ± 9 Bq/kg of ^{60}Co. The ^{212}Pb and ^{214}Pb concentrations were derived using the assumption that ^{232}Th and ^{238}U are in secular equilibrium with their decay products. NIST SRM 4355 contained 0.25 Bq/kg of ^{137}Cs on May 30, 1994. The NIST certified value was decay-corrected using the 30.17 year half life of ^{137}Cs. NIST SRM 4355 contains 585 Bq/kg ^{40}K and 43 Bq/kg ^{232}Th. The short-lived ^{212}Pb and ^{214}Pb concentrations were derived using the assumption that ^{232}Th and ^{238}U are in secular equilibrium with their decay products. The Irish Sea sediment datum was decay-corrected on March 1, 1995. The following samples were used as blind samples during the analyses of our samples: SRM 4350B, 4352 (biota surrogate), 4353, 4354, and 4355. LANL is also a Network Laboratory for the International Atomic Energy Agency (IAEA) for environmental analyses. Qualifications as a Network Laboratory is achieved and maintained by satisfactory performances on the blind QA/QC program run by IAEA. This laboratory also participates in the Inter-laboratory Calibration Program which is a QA/QC program for measuring fission products by beta-counting and high resolution gamma-ray spectrometry. In addition, LANL participates in a variety of programs that exchange split samples among several laboratories and has been producing environmental standards that are certified in the U.S. and in Europe.

2) Trace metals

Battelle Northwest Marine Science Laboratory (Sequim, WA) performed the trace metal analyses on the samples collected for our study in the Beaufort Sea. Since the inception of the NS&T Program, this laboratory has been part of the mandatory NOAA NS&T Quality Assurance /Quality Control (QA/QC) Program (Valette-Silver, 1992; Cantillo and Parris, 1993). This rigorous quality assurance program, that includes intercalibration exercises and regular analyses of blanks and standard reference material, insures accuracy, precision, and comparability of the results contributed to the NS&T Program (Valette-Silver, 1992; Cantillo and Parris, 1993).

For the trace metal analyses, Battelle Northwest Marine Science Laboratory used X-ray fluorescence following the method of the NOAA NS&T Program (Lauenstein and Cantillo, 1993). Sample dissolution is not required for the X-ray

fluorescence technique; 500 mg of either sediment or oyster tissue, dried, ground homogenized, and pressed into a pellet 2 cm in diameter, was used for the analyses.

3) Organic compounds

Battelle Ocean Science Laboratory (Duxbury, MA) performed the organic compounds analysis in the sediments and bivalve samples collected for our study in the Beaufort Sea following the method of the NOAA NS&T Program (Lauenstein and Cantillo, 1993). This laboratory participates in the NS&T QA/QC Program.

All glassware was washed with soap and water, rinsed with methanol, and dried at 200°C for a minimum of 4 hr. Prior to use, all glassware was rinsed with pesticide-grade dichloromethane or heated in a muffle furnace at 400°C for 1 hr.

Biological tissues were homogenized and 15 g aliquots were prepared for analysis. The samples were mixed and extracted with sodium sulfate and dichloromethane using a Tissumizer. The mixture was centrifuged, the supernate saved, and the operation repeated. At the end, the extracted pellet was discarded and the extract saved for analysis.

In sediment samples, pebbles, seaweed, wood, and other extraneous materials were removed. The samples were homogenized and 50 g of sediment was placed in a Teflon extraction bottle. Sediments were tumbled with sodium sulfate and activated Cu in 1:1 acetone: dichloromethane. The mixture was centrifuged, the supernate saved, and the operation repeated. At the end, the extracted sediments were discarded and the extract saved for analysis.

Both tissue and sediment extracts received a chromatographic clean-up using an alumina column followed by a concentration step in a Kuderna-Danish apparatus fitted with a three-ball Snyder column. The concentrated extract was placed in dichloromethane and underwent a chromatographic separation using size exclusion chromatography (Phenogel 100Å column). Lipids and biogenic material were discarded. Aromatic and chlorinated hydrocarbons were analyzed by gas chromatography with flame ionization detection (GC/FID) for PAHs. Gas chromatography/ mass spectrometry (GC/MS) and gas chromatography with ^{63}Ni electron capture detection (GC/ ECD) were used for PCBs and pesticides analysis.

Table 3: Radionuclides in Sediments from the West Beaufort Sea (Bq/kg d.w.)

	Min.	Max.	Mean	Median
^{137}Cs*	<2 (C1)	11.4(E7)	6.8±2.7 (n = 7)	6.2
^{137}Cs**	0.9 (E1)	12.4(E7)	4.9±3.4 (n = 12)	3.8
^{90}Sr	<0.5 (D1)	0.6 (E5)	0.42±0.25 (n = 2)	0.42
$^{239+240}Pu$	<0.03(E1)	0.52(E7)	0.21±0.16 (n = 9)	0.14
^{241}Am	0.06 (D1)	0.11(B4)	0.08±0.02 (n = 6)	0.08
^{212}Pb	22.3 (B1)	62 (E1)	41.3±11 (n = 12)	42.2
^{214}Pb	13.7 (E7)	93.3(C3)	35±24 (n = 12)	23.4
^{40}K	452 (B1)	888 (E1)	612±115 (n = 12)	588
$^{240}Pu/^{239}Pu$	0.17 (B1)	0.24(E12)	0.19±0.02 (n = 12)	0.185

*Gamma analysis; **Chemical separation; Mean are calculated for quantified values only, between parenthesis () number of analysis; Max. = Maximum; Min. Minimum; Min. and Max. between parenthesis () site location (see Appendix B1 for location); Activities not corrected for grain size. For ^{137}Cs**, grain size corrected activities are: Min = 0.9 (E1), Max = 13.45 (E7), Mean = 5.49±3.82(n = 12), Median = 4.4. ^{110}Ag, ^{65}Zn, ^{60}Co and ^{58}Co never appeared in the spectra and were always below detection limits. ^{238}Pu was always below the limit of quantification (from< 0.01 to <0.09 Bq/kg).

Table 4: Radionuclides in Biota from the West Beaufort Sea (Bq/kg d.w.)

Marine Invertebrates	**Min.**	**Max.**	**Mean**	**Median**
^{137}Cs*	<0.8	-	-	-
^{137}Cs **	0.3	1.1	0.7±0.3 (n = 6)	0.65
^{90}Sr	<0.3	-	-	-
$^{239+240}Pu$	<0.01	0.08	0.05±0.04 (n = 2)	0.05
^{241}Am	<0.02	-	-	-
^{212}Pb	<0.6	10.4	6.5±3.5 (n = 5)	3.9
^{214}Pb	<0.9	6.6	4.9±1.4 (n = 5)	4.3
^{40}K	182	309	240±45 (n = 7)	243
Vertebrates	**Min.**	**Max.**	**Mean**	**Median**
^{137}Cs *	<0.07	0.44	0.44 (n = 1)	0.44
^{137}Cs **	<0.00005	0.44	0.25±0.21 (n = 3)	0.30
^{90}Sr	<0.003	0.05	0.04±0.02 (n = 4)	0.05
$^{239+240}Pu$	<0.001	-	-	-
^{241}Am	<0.0006	-	-	-
^{212}Pb	<0.008	0.8	0.53±0.25 (n = 3)	0.50
^{214}Pb	<0.08	0.5	0.50 (n = 1)	0.50
^{40}K	10	352	161±142 (n = 7)	189

*Gamma analysis; **Chemical separation; Mean are calculated for quantified values only, () number of analysis; Max. = Maximum; Min. Minimum; Min. and Max. between parenthesis () site location (see Appendix B1 for location). ^{110}Ag, ^{65}Zn, ^{60}Co and ^{58}Co never appeared in the spectra and were always below detection limits. ^{238}Pu was always below the limits of quantification (from< 0.01 to <0.06 Bq/kg).

Results

A) Radionuclides

Except for natural radionuclides, the radioactivity of the Beaufort Sea surficial sediments and biota was generally very low, often at or below the detection limit of the analytical technique used to performed the analysis (Tables 3, 4 , Appendices A1, A2). In particular, the gamma-emitting radionuclides, ^{110}Ag, ^{65}Zn, ^{60}Co and ^{58}Co were always below detection limits in all our samples.

In the sediments, the three natural isotopes, ^{212}Pb, ^{214}Pb, ^{40}K, were generally concentrated in clay-rich material found in deep waters. In addition, the activity of the artificial radionuclides did not appear to be correlated in our samples with either the grain size or the depth of collection of the samples. If anything, the activity was slightly greater in coarser sediments than in finer ones. The lowest activities tended to be found at sites C1, D1, E1 (located away from the coast) but also at site B1 (located close to the coast). Only ^{137}Cs was detected in significant amounts (Appendices B5, B6) and the β-emitter ^{90}Sr was detected at only one site. The highest activities for ^{137}Cs and $^{239+240}Pu$ were measured in the sediments of site E7 located at 110 m depth, along the shelf break, near Point Barrow (Table 3 and Appendix A1). ^{238}Pu was never quantifiable.

In the benthic biota (Table 4 and Appendix A2), the activities of ^{137}Cs were very low and those of ^{90}Sr were often below detection limits. ^{135}Cs was undetectable in all our samples. $^{239+240}Pu$ was only measurable in two marine invertebrates samples out of 14 biological samples analyzed. ^{238}Pu and ^{241}Am were undetectable in all the samples. The activities of the natural radioisotopes, ^{212}Pb, ^{214}Pb, and ^{40}K were generally low.

In subsistence biota (Table 4 and Appendix A2), that included bowhead whale, bearded seal, and king eider, the average activity of ^{137}Cs was generally lower than in marine benthic biota (mean = 0.25 Bq/kg d.w. versus mean = 0.67 Bq/kg d.w.). In the bearded seal blubber and kidneys, all artificial radionuclides were undetectable, in king eider muscles and bones very low activities of ^{137}Cs and ^{90}Sr were detected, and lower ^{137}Cs and ^{90}Sr activities were found in bowhead whale lungs and blubbers than in livers.

B) Trace Metals

Trace metals were measured in sediments (Table 5 and Appendix A3) collected during the Polar Star cruise (Appendices B7-B22), but not in the biological samples.

The sediments of the Beaufort Sea are silico-aluminate sediments, as can be seen from the concentrations of the major elements (Al, Si, Fe, and Mn). Among the trace elements, the highest concentrations were found for Zn, Cr, Ni, and Cu (35 to 121 ppm). As and Pb were present in a lower concentration range (19 to 29 ppm). The other metals, i.e., Sn, Sb, Se, Cd, Hg, and Ag, were at concentrations less than 5 ppm.

The grain size coefficient given for sediments in Appendix A1, is derived from the proportions of fine particles (<63 μm) in the sediments. This coefficient was used to obtain corrected contaminant concentrations. The highest concentrations (corrected or uncorrected for grain size) of Ag and As were observed at site G11, located in the Barrow Canyon. The highest concentrations for most of the trace and major elements were found at sites further from land (Cd, and Hg at C1; Sb, Zn and Mn at C3; Ni and Fe at D1; Cu, Pb, Sn and Al at E1). The shallowest site visited during the cruise, B1 (34m), had the coarsest sediments and the lowest uncorrected concentrations for most of the elements.

Table 5: Metal Concentrations in Sediments of the West Beaufort Sea
(in ppm d.w.)

	Ag	As	Cd	Cr	Cu	Hg
Max	0.13(G11)	43(G11)	0.43(C1)	110(E12)	63(E1)	0.15(C1)
Min	0.03(C3)	10.4(B1)	0.06(B1)	77(E7)	11(B1)	0.04(B1)
Av.	0.07±0.03	29±12	0.15±0.11	87±11	35±17	0.076±0.031
Av. C	0.08±0.05	32±13	0.16±0.11	97±19	37±16	0.083±0.028

	Ni	Pb	Sb	Se	Sn	Zn
Max	75(D1)	25(E1)	3.12(C3)	0.63(B1)	3.3(E1)	160(C3)
Min	21(B1)	11(B1)	0.79(B1)	0.08(D1)	1.6(B1)	65(B1)
Av.	46±18	19±5	1.57±0.73	0.36±0.22	2.3±0.5	121±29
Av. C	49±16	20±4	1.71±0.72	0.41±0.28	2.5±0.3	131±18

	Al*	Fe*	Si*	Mn*
Max	8.0(E1)	5.2(D1)	33(B1)	1.30(C3)
Min.	4.7(B4)	2.6(B1)	23(D1)	0.03(E12/B1)
Av.	6.2 ±1.1	4.4 ± 0.8	26.7 ± 2.8	0.4 ±0.4
Av. C	6.9±1.2	4.8 ± 0.5	30.3 ± 8.6	0.4 ±0.4

*Elements expressed in %; Max = Maximum; Min = Minimum; Av. = Average; Max, Min, Av. = uncorrected values; Av. C = Average of grain size corrected concentrations using the grain size coefficient given in Appendix A1; () Name of sites (see Appendix B1 for location); Average based on n = 10, except for Ag, n = 8;

C) Organic compounds

1)Polycyclic Aromatic Hydrocarbons (PAHs)

*Sediments

In the Beaufort Sea, concentrations (not corrected for grain size) of total resolved PAHs in offshore surficial sediments ranged between 159 and 1092 ng/g d.w. (Table 6, Appendices A4a and b, B31). The highest concentrations were observed at site E-1, the deepest site sampled during the Polar Star cruise (3813m).

In the sediments analyzed here, large proportions of total naphthalenes (tNaph between ~25% and ~54% of the total PAHs), total phenanthrenes/anthracenes (tPhen from ~ 8% to ~41% of the total PAHs), total chrysenes (tChry from ~2% to over 12% of the total PAHs), and total dibenzothiophenes (tDiben from 2.8% to 7.5% of the total PAHs) were found in the total PAHs (Appendices B23-B32). Finally, the concentration of the last major group of compounds, the total fluorenes (tFluor), was very low, constituting always less than 1% of the total PAHs (between 0.6% and 0.8%). Perylene (Appendices B 29, B30) concentrations were fairly elevated (up to about 56 ng/g), constituting from 1.8% to 9.6% of the total PAHs (average 4.2%).

At 6 of the 10 stations sampled during the cruise, the individual compounds C1-phenanthrene/anthracenes were the major constituents of the PAHs (8% to 10% of the tPAHs). At the remaining sites, C2-naphthalenes were the major constituents, constituting between 7.5% and 12.5% of the total PAHs.

Table 6: PAH Concentrations* in Sediments of the West Beaufort Sea (ng/g d.w.)

	tNaph	tFluor	tPhen	tDiben	tChry	Per	tPAHs
Max	319(E1)	6.3(G11)	369(E1)	76(E1)	128(E1)	55.9(G11)	1092(E1)
Min	54(B1)	0(B1, E7)	21(E7)	0(B1, E7)	5(E7)	1.9(D1)	159(B1)
Av.	147±87	6.7±0.6	158±106	37±23	49±37	20.5±15	488±298
%AvTP	32	0.7	3	6	9.6	4.2	100

Max = Maximum; Min = Minimum; Av. = Average (average based on n = 10); tNaph = Total naphthalenes; tFluor = Total fluorenes; tPhen = Total phenanthrenes/anthracenes; tDiben = Total dibenzothiophenes; tChry = Total chrysenes; tPAHs = Total polyaromatic hydrocarbons; %AvTP = Percent of the average total PAHs. () Site number.
*Concentrations not corrected for grain size.

*Biota

During the Polar Star cruise (Appendix B1) in the Beaufort Sea, biological samples were only collected at three sites: G-1 (44 m depth), E-7 (113m depth) and B-4 (52 m depth). The concentrations of PAHs in the biota collected in this

study are given in Table 7 and in Appendix A5. The concentration of total resolved PAHs in Polar Star marine biota ranged from 24 to 161 ng/g dry weight. The highest concentrations were observed in nudibranchs collected at site G-1(site closest to shore) and in *Macoma calcarea* samples, collected at site B-4. These sites are located at similar depths (44 m and 52 m, respectively).

Table 7: PAH Concentrations in Biota of the West Beaufort Sea (ng/g d.w.)

	tNaph	tFluor	tPhen	tDiben	tChry	Peryl	TPAHs
Max.	57(B4-MC)	6.8(G1-SU)	25(B4-MC)	ND	41(G1-N)	28.8(G1-N)	161(G1-N)
Min.	11(G1-SU)	ND	ND	ND	ND	1.5(G1-SS)	24(G1-C)
Av M. In.	26±14	6.8	11.6±10.3	ND	17±21	11±9	67±52
%AvTP	38	10	17	ND	25	16	100
Av M. Vt.	20	ND	ND	ND	ND	ND	20

Max. = Maximum; Min. = Minimum; Av. = Average; M. In = Marine invertebrates; M.Vt = Marine vertebrates. tNaph = Total naphthalenes; tFluor = Total fluorenes; tPhen = Total phenanthrenes/anthracenes; tDiben = Total dibenzothiophenes; tChry = Total chrysenes; Peryl = Perylene; TPAHs = Total polyaromatic hydrocarbons; %AvTP = Percent of the average total PAHs. () Site number. MC = *Macoma calcarea*; SU = Sea urchin; N = Nudibranchs; C = Clam; SS = Small shrimps. ND = Below detection limits.

In the Polar Star biota samples, total naphthalenes (tNaph) always constituted the largest fraction of the total PAHs, ranging from ~12% to 100% of the tPAHs. In fact, tNaph (~20 ng/g) were the only category of PAHs found in the fish samples (PAHs analyzed on fish whole body). In the fish samples, all the other constituents were below detection. In 6 of the 10 samples of marine biota, naphthalene was the major constituent (representing between 6% and ~77% of the total PAHs). At the remaining sites, C1 and C2-naphthalenes were the most abundant categories of the total PAHs. For example, in the carid shrimps collected at site G-1, tNaph equaled 16.6 ng/g d.w., and in *Macoma calcarea* sampled at site B-4, tNaph equaled 28.2 ng/g d.w., values corresponding to 24% and 19% of the total PAHs respectively .

In contrast to the other biological specimens, total chrysenes (tChry) and especially C2-chrysenes (C2-Chry) constituted the largest fraction of the tPAHs in nudibranchs (~26% of tPAHs for tChry and ~16% of tPAHs for C2-Chry). The highest perylene concentrations were also found in the nudibranchs collected at site G-1 (~18% of the total PAHs).

In the marine biota, total phenanthrenes/anthracenes (tPhen) constituted between 0% and ~13% of the total PAHs and total chrysenes (tChry) between 3 % and 25% of the total PAHs. Total dibenzothiophenes (tDiben) were always below detection. Finally, the concentrations of the last major group of PAH compounds, the

total fluorenes (tFluor), were very low, always below detection except in the sea urchin collected at site G-1 (~20% of total PAHs). Perylene was also present in the marine biota samples in fairly large amounts ranging from 1.52 to 28.84 ng/g d.w. (4.5% to 18% of tPAHs).

2)Organochlorine compounds

*Sediments

In most of the Beaufort Sea surficial sediments, concentrations of polychlorinated biphenyls (PCBs) and pesticides (Table 8 and Appendices A6, B33-40) were very low. The total PCBs concentrations (not corrected for grain size) ranged from 0.54 ng/g at station B-1 to 2.51 ng/g at station G-11. In our samples, the most abundant PCB congeners were the congeners Cl3 (18) and (23), Cl4 (44) and (66), and Cl5 (118). These congeners constituted between 26% and 57 % of the total PCBs. The planar congeners Cl4 (77) and Cl5 (126) were always below detection.

Table 8: Organochlorine Compound Concentrations in Sediments of the West Beaufort Sea
(ng/g d.w.)

	tPCBs	tPest.	tDDTs
Max.	2.51(B1)	0.92(G11/E12)	0.78(E1)
Min.	0.54(G11)	0(D1)	0(D1/E5)
Ave.	1.04±0.6 (n = 10)	0.58±0.3 (n = 10)	0.39±0.3 (n = 10)

Max. = Maximum; Min. Minimum; Ave. Average; TPCBs = Total polychlorinated biphenyls; tPest Total pesticides; tDDTs = Total DDT and its metabolites. () Site number; n = number of concentrations used to calculate the average.

The chlorinated pesticides concentrations were very low, most of them being below detection. The total pesticide concentrations ranged from undetected (station D-1) to 0.92 ng/g (stations E-12 and G-11). Lindane was present in 6 samples out of 10 (Appendices B39-40). Other compounds, such as heptachlor, heptachlorepoxide, cis-chlordane and dieldrin appeared sporadically, occurring in samples G-11, B-1, B-4 and E-1. DDT (2, 4 and 4, 4) and/or some of its metabolites, 2, 4-DDE, 4, 4-DDE and 2, 4-DDD were found in all samples but two (E-5 and D-1); 4, 4-DDE was the compound most often found. The tDDTs ranged from undetected (stations D-1; E-5) to 0.78 ng/g (station E-1).

***Biota**

Most of the Beaufort Sea biological samples had very low concentrations of total PCBs and chlorinated pesticides (Table 9 and Appendix A7). The total PCBs concentrations ranged from 2.43 ng/g in small shrimp to 31 ng/g in sea urchin, both collected at station G-1.

PCBs Cl 2(08), Cl 4(52) and Cl 5(101), and (105) were the most abundant congeners in our samples. When present, congener PCB(08) often constituted between 75% and 100% of the tPCBs, the other congeners contributing between 22% to 28% of the total PCBs. The planar congeners Cl4 (77) and Cl5 (126) were always below detection.

The chlorinated pesticide concentrations were very low, most of them being below detection. The total pesticide concentrations ranged from 2.35 ng/g (sea urchins, G-1) to 26.87 ng/g (hermit crabs, G-1) with the tDDTs ranging from below detection (clams, G-1 and *Macoma calcarea*, B-4) to 3.22 ng/g (sculpin, G-1). Hexachlorobenzene was identified in all samples; trans-nonachlor and dieldrin were detected in all samples but one (B4-*Macoma calcarea*); cis-chlordane in all but two (B4-*Macoma calcarea*; G1-clams); and heptachlorepoxide in all but three.

4, 4 DDT and/or some DDT metabolites, i.e., 2, 4-DDE, 4, 4-DDE and 4, 4-DDD were found in the samples, 4, 4-DDE being one of these compounds found most often (7 samples out of 10). Other compounds, such as lindane (5 samples out of 10), heptachlor, and mirex (in carid shrimps, site G-1), were found in some of the samples. The fish samples displayed about twice the total DDTs and total pesticide concentrations found in the invertebrates.

Table 9: Organochlorine Compound Concentrations in Biota of the West Beaufort Sea
(ng/g d.w.)

	tPCBs	tpest.	tDDTs
Max. M. Inv.	31(G1-SU)	27(G1-HC)	1.87(G1-CS)
Min. M. Inv.	2.4(G1-SS)	2.4(G1-SU)	0(B4-MC/G1-C)
Ave. M. Inv.	12.2±8.6(n = 9)	9.5±7.3(n = 9)	0.74±1.00(n = 9)
Mar. Vert.	8.0	19.1	3.2

Max. = Maximum; Min. = Minimum; Ave. = Average; M. Inv. = Marine invertebrates; Mar. Vert. = Marine vertebrates; n = number of concentrations used to calculate the average.
TPCBs = Total polychlorinated biphenyls; Tpest = Total pesticides; TDDTs = Total DDT and its metabolites. () Site number. SU = Sea urchin; C = Clam; SS = Small shrimps; HC = Hermit crabs; CS = Carid shrimps.

Table 10: Range of Metal Concentrations in Alaskan NS&T Samples

(μg/g d.w.)

MOLLUSKS

	Ag	As	Cd	Cr	Cu	Hg
Max	0.04 (10)	12.3(10)	3.1(13)	3.58(10)	11.18(10)	0.09(13)
Min	0.03 (13)	10.8(13)	2.5(10)	3.11(13)	9.40(13)	0.06(10)
Aver*	0.033 ± 0.005	11.6 ± 1.02	2.8 ± 0.43	3.35 ± 0.33	10.29 ± 1.25	0.08 ± 0.02

	Ni	Pb	Sb	Se	Sn	Zn
Max	2.76(10)	1.44(10)	4.01(13)	4.01(13)	0.09(10)	95.60(13)
Min	2.03(13)	1.05(13)	0.08(10)	3.87(10)	0.04(13)	81.72(10)
Aver*	2.40 ± 0.52	1.24 ± 0.27	2.05 ± 2.78	3.94 ± 0.10	0.07 ± 0.04	88.66 ± 9.81

FISH LIVERS (Flathead Sole)

	Ag	As	Cd	Cr	Cu	Hg
Max	0.17(6)	84.8(5)	2.01(11)	1.00(3)	49.3(7)	0.43(3)
Min	0.06(4, 8)	7.8(12)	0.03(3)	0.16(5)	2.4(1)	0.02(8)
Aver	0.10 ± 0.04	34 ± 26	1.1 ± 0.64	0.36 ± 0.27	18.0 ±13.9	0.19 ± 0.16

	Ni	Pb	Mn	Se	Sn	Zn
Max	0.71(2)	4.25(12)	10.4(3)	18.3(11)	0.72(9)	128(2)
Min	0.20(3)	0.00(11)	0.74(12)	2.6(4)	0.21(8)	83(4)
Aver	0.47 ± 0.18	0.63 ±1.37	4.73 ± 2.87	10.03 ± 5.56	0.47 ± 0.14	104 ± 15

SEDIMENTS

	Ag	As	Cd	Cr	Cu	Hg
Max	0.42 (12)	25.7(10)	1.09(9)	213(6)	66(10)	0.24(3)
Min	0.01(6)	1.01(9)	0.0(6)	23.3(9)	9.8(9)	0.02(6)
Aver**	0.20±0.12	5.4±6.9	0.38±0.3	88±57	28.9±19	0.1±0.08
Av. C	0.34 ± 0.22	9.64 ±10	0.91 ±1.45	237 ± 336	52 ± 40	0.2 ± 0.2

	Ni	Pb	Sb	Se	Sn	Zn
Max	66(10)	52(12)	2.87(10)	0.87(9)	3.37(4)	191(9)
Min	4.3(12)	7.9(2)	0.16(6)	0.06(4)	0.07(9)	51(6)
Aver**	20.7 ± 19	19.6 ± 13	1.07 ± 0.8	0.39 ± 0.25	1.97 ± 1	118 ± 45
Av. C	42 ± 46	38.5 ± 33	2.2 ± 2.7	0.65 ± 0.35	6.4 ± 11	264 ± 315

Site numbers between parenthesis: (1) BEAOP, Oliktok Point; (2) BEAPB, Prudhoe Bay; (3) BERDH, Dutch Harbor; (4) BOCBP, Boca de Quadra; (5) CHKRD, Red Dog Mine; (6) GOAKB, Kamishak Bay; (7) LUTCR, Lutak Inlet; (8) PWSPV, Port Valdez; (9) SKASR, Skagway River; (10) PVMC, Mineral Creek Flats; (11) UISB, Siwash Bay; (12) NAHES, Nahku Bay; (13) BERPM, Port Moller. Max = maximum, Min = minimum, Aver. = Average, Aver. Cor = average of grainsize corrected concentrations for sediments, N.Av.C. = National average for corrected values. *Data from O'Connor and Beliaeff, 1995; **Data after O'Connor, 1988.

Table 11: Range of Organic Contaminant Concentrations in Alaskan NS&T Samples

(ng/g d.w.)

MOLLUSKS

	Hexachlor	Lindane	Mirex	tCdane
Max	0.64(13)	2.39(13)	ND	1.94(13)
Min	0.48(10)	1.71(10)	ND	1.00(10)
Aver*	0.56 ± 0.11	2.05 ± 0.48	ND	1.47 ± 0.67
	tDield	**tDDT**	**tPCB**	**tPAH**
Max	0 .79(13)	1.86(10)	48.9(10)	217(10)
Min	0.36)10)	1.3(13)	35.7(13)	15913)
Aver*	0.57 ± 0.31	1.60 ± 0.36	42.3 ± 9.35	188 ± 41

FISH LIVERS (Flathead Sole)

	Hexachlor	Lindane	Mirex	tCdane
Max	42.6(2)	4.67(9)	3.33(9)	71.7(5, 9]
Min	1.33(3)	ND	1.20(2)	12.7(6)
Aver*	13.6 ± 12.7	2.81 ± 1.71	2.02 ± 0.81	40.3 ± 10
	tDield	**tDDT**	**tPCB**	
Max	15.33(1)	247(5)	2191(8)	
Min	1.67(4)	17(6)	127(4)	
Aver	7.65 ± 5.24	109 ± 85	587 ± 586	

SEDIMENTS

	Hexachlor	Lindane	Mirex	tCdane
Max	0.73(7)	1(4)	0.06(2)	0.33(11)
Min	0.02	0.13	0.06	0.03
Aver**	0.35 ± 0.23	0.54 ± 0.36	0.06	0.16
	tDield	**tDDT**	**tPCB**	**tPAH**
Max	ND	4.67(4)	59(3)	733(1)
Min	ND	0.17	1.63(10)	2.17
Aver**	ND	1.32 ± 1.47	21 ± 17.5	289 ± 316

Site numbers between parenthesis: (1) BEAOP, Oliktok Point; (2) BEAPB, Prudhoe Bay; (3) BERDH, Dutch Harbor; (4) BOCBP, Boca de Quadra; (5) CHKRD, Red Dog Mine; (6) GOAKB, Kamishak Bay; (7) LUTCR, Lutak Inlet; (8) PWSPV, Port Valdez; (9) SKASR, Skagway River; (10) PVMC, Mineral Creek Flats; (11) UISB, Siwash Bay; (12) NAHES, Nahku Bay; (13) BERPM, Port Moller. Max = maximum, Min = minimum, Aver. average, Aver. Cor = average of grainsize corrected concentrations for sediments, N.Av.C. = National average for corrected values. Bivalve data for soft tissues. *Data from O'Connor and Beliaeff, 1995; **Data after O'Connor, 1988. New sites have been sampled in 1995 by the Mussel Watch Project. These data are not included in the calculation of the averages.

Previous NS&T results

Surficial sediments collected offshore in the Beaufort Sea since the mid-1970s have been analyzed in a number of studies. In particular, the NOAA NS&T Program has developed, since the mid-1980s, a nationally consistent database on the distribution of a broad suite of chemical contaminants including metals (antimony, arsenic, cadmium, chromium, copper, iron, lead, nickel, mercury, selenium, silver, tin, and zinc) and organic compounds (chlorinated pesticides, PCBs, PAHs, total butyl tin) in the U.S. coastal waters (Daskalakis and O'Connor, 1995).

Thirteen stations were established along the coast of Alaska between 1984 and 1990 as part of the NS&T Program (Appendix C1). Three of these sites are located in the U.S. Arctic and the rest along the south coast of Alaska (Appendix C1). Sediments, mollusks, and fish tissues samples were collected and analyzed for metals (Table 10; Appendices A8-A9; Appendices C2-C24) and organic compounds (Table 11 and Appendices A10-A15; Appendices C25-C35). The results show that in Alaska contamination in trace metals and organic compounds is present in sediments as well as in biota around mining districts and harbors.

Interpretation of Results

One characteristic of all the samples collected in the Beaufort Sea is that the concentrations of both radionuclides and organic compounds were very often undetected in the sediments as well as in the biota. Trace metal concentrations in the sediments generally reflected country rocks concentrations and generally pristine conditions, consistent with most of the coastal areas of Alaska.

A) Radionuclides

The origin of the radionuclides found in west Beaufort Sea is natural for isotopes such as ^{40}K (T1/2 = 1.28x109 y), ^{212}Pb (T1/2 = 10.64h), or ^{214}Pb (T1/2 = 26.8m) and anthropogenic for nuclides such as ^{90}Sr (T1/2 = 28y), ^{137}Cs (T1/2 = 30y), ^{238}Pu (T1/2 = 86y), ^{239}Pu (T1/2 = 24 400y), ^{240}Pu (T1/2 = 6580y), and ^{241}Am (T1/2 = 458y).

^{40}K in sediments is associated with K-rich minerals such as feldspars and clay minerals, while ^{212}Pb and ^{214}Pb are short-lived species in the ^{232}Th and ^{238}U decay series, respectively, and are also associated with sedimentary minerals (Gourlez *et al.*, 1976; Somayajulu *et al.*, 1989). These radioisotopes are called

terrestrial radionuclides or primordial radionuclides and were formed at the same time as the earth was formed, several billion years ago (Tykva and Sabol, 1995).

Global fallout derived from weapons testing in the atmosphere (Mamuro and Matsunami, 1969), operation of nuclear facilities in NW Europe such as the reprocessing plants at Sellafield (United Kingdom) and La Hague (France), U.S. peaceful use tests in the Arctic and nuclear activities in the Former Soviet Union, including testing areas, accidents, improper storage of nuclear wastes, and unauthorized ocean dumping of nuclear material, are the potential sources for the anthropogenic radioactivity found in the Arctic.

•Atmospheric testing (Carter and Moghissi, 1977; Koide *et al.*, 1977; Aarkrog, 1993; Valette-Silver and Lauenstein, 1995; Wright *et al.*, 1997)

The United States, the Former Soviet Union, the United Kingdom, France, and China conducted 518 atmospheric weapons tests (Norris and Arkin, 1996; Strand and Holm, 1993; Strand *et al.*, 1997). Approximately 1.2×10^{16} Bq of $^{239+240}Pu$ and 4×10^{15} Bq of ^{241}Am were released into the atmosphere by these tests from the 50s to the 80s. Most of the global fallout was deposited in the Northern Hemisphere. The global fallout is a complex mixture whose isotopic composition is influenced by the type of nuclear device being tested, the location of the tests and the mechanisms of atmospheric transport, diffusion, and fractionation processes.

•Nuclear Facilities in NW Europe (Joint Russian-Norwegian Expert Group, 1993; Aarkrog, 1993; Pryde and Bradley, 1994; OTA, 1995).

The operation of the nuclear reprocessing facilities located in NW Europe has resulted in the controlled release of low-level radioactive waste into coastal waters. By 1985, La Hague (France) discharged 7.6×10^{14} Bq ^{137}Cs, 6.75×10^{14} Bq ^{90}Sr, and 3×10^{12} Bq of plutonium (Calmet et Guegueniat, 1985). From 1952 to 1991, Sellafield (United Kingdom) released 2.9×10^{16} Bq ^{137}Cs, 4.2×10^{15} Bq ^{90}Sr, and 6.9×10^{14} Bq $^{239+240}Pu$. The radionuclides liberated are quickly adsorbed onto particles that can be quickly deposited on the ocean floor. Near Sellafield, $^{239+240}Pu$ in the sediments has reached a level of 4240 Bq/kg (OTA, 1995).

•Activities in the Former Soviet Union (Baskaran *et al.*, 1991; Joint Russian-Norwegian Expert Group, 1993; Aarkrog, 1989; 1993; Pryde and Bradley, 1994; OTA, 1995):

-The Chernobyl accident occurred in April 1986. At that time, the N4 reactor released 3.7×10^{18} Bq of radioactive material (mostly ^{137}Cs) which was distributed over large geographical areas, including Northern Europe and Canada (Baskaran *et al.*, 1991; Aarkrog, 1989; Pyatt and Beaumont, 1992; Wright *et al.*, 1997).

-The Semipalatinsk test area contaminated the Altay region (Pryde and Bradley, 1994; OTA, 1995) with ^{137}Cs (on the order of $5.6X10^{9}$ Bq/km^2), ^{90}Sr (about $11X10^{8}$ Bq/km^2), and $^{239+240}Pu$ (~$4.6x10^{8}$ Bq/km^2).

-In the Urals, radioactive contamination associated with the functioning of the Mayak (formerly Cheliabinsk-65) facility is due to several factors (Joint Russian-Norwegian Expert Group, 1993; Aarkrog, 1989; 1993; Pryde and Bradley, 1994; OTA, 1995):

°Between 1949-1956 about $7.6x10^{7}$ m^3 of liquid radioactive waste ($1x10^{17}$ Bq) was discharged into the Techa River with most of the radioactivity being adsorbed onto the sediments of the upper reaches of the river.

°An explosion occurred in 1957 at the facility that spread radionuclides in the environment.

°Finally, part of the facility's radioactive wastes were stored in ground and surface storage tanks, water reservoirs, geological formations, and in Karachi Lake. In 1967, the lake became dry and suspension of radioactive materials from the lake shores and bottom by the wind spread large quantities of radioactive material over a large area. Sediments, collected in 1993 at a site located 78 Km downstream from the facility, still displayed 0.08 Bq/kg ^{90}Sr, 0.1 Bq/kg ^{137}Cs, and 0.001 Bq/kg ^{239}Pu. Ultimately, the Techa River empties into the Ob River which flows into the Arctic Ocean.

-In western Siberia, many caches of radioactive material ($7.4x10^{19}$ Bq) as well as two facilities, Tomsk-7 and Krasnoyarsk-26, are believed to be responsible for the contamination found in the major rivers feeding the Arctic Ocean through the Kara Sea(Joint Russian-Norwegian Expert Group, 1993; Aarkrog, 1989; 1993; Pryde and Bradley, 1994; OTA, 1995; Fisher ,1995; Fisher *et al.*, 1995).

-A number of nuclear tests were conducted in various points of the Arctic area but most of all at the Central Testing Ground for Nuclear Weapons on Novaya Zemlya Island. These tests released $4.8x10^{17}$ Bq of ^{137}Cs into the atmosphere from 1945-1962 (Joint Russian-Norwegian Expert Group, 1993; Aarkrog, 1989; 1993; Pryde and Bradley, 1994; OTA, 1995).

-Large volumes of liquid (6000-7000m^3) and solid (45000m^3) radioactive waste are generated annually by the Northern Fleet operations. Seventy percent of this is associated with activities in the Barents Sea region. Dumping of radioactive wastes, including reactors, low-level, and liquid waste, occurred in the Kara Sea and elsewhere in the Arctic Ocean until 1992. These disposals are estimated to have contained $8.6x10^{16}$ Bq of radioactivity (Joint Russian-Norwegian

Expert Group, 1993; Sjoeblom and Lindsey, 1993; Aarkrog, 1989; 1993; Pryde and Bradley, 1994; OTA, 1995, Fuhrmann and Dyer, 1995; Foyn, 1995).

1) Distribution of Radionuclides in West Beaufort Sea

*Sediments

For the sediments collected during the USCG Polar Star cruise, all the data are presented in Bq/kg dry weight. In the literature, if no information was provided, we assumed that the data were also expressed in Bq/kg (or equivalent units) dry weight.

•Natural radionuclide

In the west Beaufort Sea sediments (Appendix A1), concentrations of the natural radionuclides ^{40}K, ^{212}Pb, and ^{214}Pb are very similar to those found in other areas of the Arctic. For example, in the Barents and Kara Seas concentrations ranging from 86 to 811 Bq/kg (average 400 ± 160 Bq/kg; Ivanov *et al.*, 1993) have been detected. The distribution of these nuclides correlated somewhat with depth but was better correlated with the percent of fine-grained material (e.g., r = 0.80 for the correlation between ^{40}K and clay fraction and r = 0.67 for the correlation of ^{40}K with depth). The highest activities of these three natural isotopes were found at location E-1, which was not only the deepest station visited during the Polar Star cruise but also where the highest percentage of fine sediments was found (56% clays). These sediments were also the richest in Al (8%), showing that they are rich in potassium-rich clay minerals.

•Artificial radionuclides

As noted in the results section, the activities of artificial radionuclides in the west Beaufort Sea sediments were generally low. In fact, the activities measured in this study were lower than those measured in other areas of the Arctic (Smith and Ellis, 1994). This observation is in good agreement with the results obtained by other authors (Baskaran and Naidu, 1995; Cooper *et al.*, 1995a;1995b) for sediments collected in the Chukchi and Beaufort Seas, and with results obtained for sediments collected in other areas of the U.S. (Table 12; Curtis and Dyer, 1993), the Arctic Ocean (Matishov *et al.*, 1993; Smith and Ellis, 1994; Forman *et al.*, 1995) and the world (Crane, 1995; Roos and Holm, 1993; Roos *et al.*, 1993a, 1993b; Hong *et al.*, 1995).

In our samples, no clear correlation were seen between artificial radionuclide activities and depth (r = -0.35 for $^{239+240}Pu$ and depth), sediment grain size (r = 0.38 for ^{137}Cs and clay) and total organic carbon (TOC) content of the sediments (r = 0.58 for $^{239+240}Pu$ and TOC). The grain size corrected activities were generally slightly higher than uncorrected activities, but the correction does not change the basic

observation. For example, ^{137}Cs activity at station E7 increased only from 12.40 to 13.42 Bq/kg d.w. after correction and the three sites E7, E5, and G11 still have the highest activities measured at all the stations.

Table 12: Radionuclides in Coastal U.S. Sediments*
(after Curtis and Dyer, 1993)

Location	137Cs**	238Pu**	239+240Pu**
Boston Harbor	2.22	ND°°	0.74
	0.74	ND	0.37
	3.33	ND	0.74
Raritan Bay	1.48	ND	0.74
Delaware Bay	1.85	ND	0.37
Chesapeake Bay	ND	ND	0.37
Charleston Harbor	2.22	ND	0.74
Sapelo Sound	2.22	ND	0.37
San Francisco Bay	0.74	ND	0.37
	1.11	ND	0.37
	1.85	ND	0.37
	5.92	ND	0.37
Farallon Islands°°	1.48	ND	0.74
Coos Bay	2.59	ND	0.74
Average U.S.	2.13±3.41	ND	0.85±0.16
Range U.S.	ND to 5.92	ND	0.37 to 0.74
Average E. Chukchi Sea°	2.90	-	-
Range E. Chukchi Sea°	2.43 to 3.97	-	-
Average W. Beaufort Sea	4.92±3.41	ND	0.21±0.16
Range W. Beaufort Sea	0.9 to 12.4	ND	<0.03 to 0.52

°After Baskaran and Naidu, 1995 ; °°Suchaneck and Lagunas-Solar, 1993
°°ND = Not detected.
*Top 5 cm of bottom sediments
* *Data are given with an approximate 35% uncertainty for ^{137}Cs and 20% error for Pu; Activity in Bq/kg d.w.

^{137}Cs

^{137}Cs is the only anthropogenic isotope that was consistently measured in both sediments and biological samples. Compared to other U.S. coastal sediments (Baskaran *et al.*, 1991; Curtis and Dyer, 1993; Baskaran and Naidu, 1995), the ^{137}Cs activity of the west Beaufort Sea sediments is slightly elevated (about double). In our data, some of the samples had activities greater than 10 Bq/kg d.w. and these results were confirmed by an independent study performed by Cooper *et al.* (1995a). They are not associated with the variability (Table 3) of the sediment grain size (Cooper *et al.*, 1997). These higher activities observed in the surficial sediments could be related

to the impact of the Chernobyl accident on northern latitudes (White *et al.*, 1986; Goldman, 1987; Aarkrog, A., 1988; 1889; Baskaran *et al.*, 1991), to the presence of on-land ^{137}Cs- rich sources (Cooper *et al.*, 1995a), or to the arrival, via the Arctic Ocean (Herman, 1989), of the European reprocessing plant signal (Ellis *et al.*, 1997). In addition, the estimated distribution of deposition from the nuclear weapons test fallout show that in the Arctic, the highest deposition occurred in coastal zones of Norway and Alaska (Cambray and Eakins, 1980; Cawse and Horrill, 1986). However, our data are too few to get into a more elaborate interpretation and a more detailed study is needed to understand the meaning of these elevated values.

In uncontaminated areas of the Arctic, surficial sediments have ^{137}Cs activities that vary from 0.2 to 11.8 Bq/kg (Smith and Ellis, 1994; Dahlgaard, 1993). Sediments collected in the Pacific Ocean near Korea display ^{137}Cs activities ranging from 0.55 Bq/kg for the Yamato Rise to 1.06 and 1.01 Bq/kg for the Korea Plateau and the Uleung Basin, respectively (Hong *et al.*, 1995).

In other areas of the Arctic, located close to local sources of contamination (such as the dumping /testing grounds of the Former Soviet Union) but not directly impacted by them, ^{137}Cs activities are higher, ranging from 2 to 11.2 Bq/kg in the St. Anna Trough located in the northern Barents Sea, north of the Novaya Zemlya testing grounds (August *et al.*, 1995), and reaching 4.9 Bq/kg in the Norwegian Sea, 8.8 Bq/kg near the Kola Peninsula and 11 Bq/kg close to Novaya Zemlya (Smith and Ellis, 1994). These variations were explained by Smith and Ellis (1994) mainly on the basis of particle size and organic contents of the sediments. These values were very similar to those found in the samples collected in west Beaufort Sea. Finally, western Beaufort Sea sediment activities were low compared to the very contaminated areas of the Russian Arctic such as Chernaya Bay, a fjord located on the south coast of Novaya Zemlya where underwater nuclear tests were conducted in the 1950's and 60's. In this area, very elevated levels of ^{137}Cs (1444 Bq/kg, Matishov *et al.*, 1993; 158 Bq/kg, Smith and Ellis, 1994) were measured. Also, a few elevated activities of ^{137}Cs were measured in sediments collected in 1993-94 in the Ob and Yenisey Rivers, in the Kara Sea (maximum 71.4 Bq/kg, Brooks *et al.*, 1994; 1995), and in the Techa River that empties into the Ob River and reaches the Kara Sea (about 200 Bq/kg, Trapeznikov *et al.*, 1993). Samples collected in Antarctic lakes, such as Lake Zano (South Shetlands Islands), also display high activities (248 Bq/kg) of ^{137}Cs (Roos *et al.*, 1993).

$^{239+240}$Pu

In the sediments collected in west Beaufort Sea, $^{239+240}$Pu activities ranged from <0.03 to 0.52 Bq/kg (average 0.21±0.16 Bq/kg), values which are lower (about 4 to 5 times less) than the activities measured in other Arctic areas (Smith and Ellis, 1994). For example, $^{239+240}$Pu activity reaches 0.8 Bq/kg in the Norwegian Sea, 1.1 Bq/kg near the Kola peninsula, and 9 Bq/kg close to Novaya Zemlya (Smith and Ellis, 1994). In very contaminated areas of the Kara Sea, $^{239+240}$Pu activities reaching 8470 Bq/kg (Smith and Ellis, 1994) to 11, 148 Bq/kg (Forman *et al.*, 1994; 1995) have been detected. Compared to the coasts of Korea in the Pacific Ocean (0.98 Bq/kg on the Yamato Rise, 2.05 Bq/kg in the Uleung Basin, and 2.57 Bq/kg on the Korea Plateau), the $^{239+240}$Pu activities of the sediments from the western Beaufort Sea are about one order of magnitude lower (Hong *et al.*, 1995). In Antarctic lakes (Roos *et al.*, 1993), 11.4 Bq/kg of $^{239+240}$Pu were detected in the surface sediments. This is about 50 times higher than the levels measured in the samples collected during the Polar Star cruise.

^{90}Sr

As observed for the other radionuclides, ^{90}Sr (west Beaufort Sea average = 0.42±0.25 Bq/kg), ^{241}Am (west Beaufort Sea average = 0.08± 0.02 Bq/kg), and ^{238}Pu (west Beaufort Sea below detection limits, <0.2 Bq/kg) activities were very low and in a similar range or lower than most of the values obtained from other areas in the U.S. or the world (for example, ^{90}Sr activity = 7.5 Bq/kg in the Uleung Basin in the Pacific; Hong *et al.*, 1995).

*Biota

By the fact that the biological samples were collected at only three stations (B4, E7, and G1), no real geographical patterns can be extracted from our data.

•Natural radionuclides

Among the marine invertebrates, the borrowing sipunculids from Station B4 displayed the highest activities for all three natural radionuclides. This is more likely due to the ingestion by the animals of fine sedimentary particles enriched in radioactive material. Compared to the data obtained by the NS&T Program for bivalves collected around the coastal U.S. (Table 13), west Beaufort Sea invertebrates displayed similar or lower ^{40}K activities (Valette-Silver and Lauenstein, 1995).

In the subsistence biota, the kidneys of the bearded seals contained the highest activities of the natural radionuclides. These animals are mostly benthic feeders, 90%

of their diet being composed by clams, shrimps, worms, etc. and less than 10% by fish. As discussed previously, benthic invertebrates often retain sediment particles in their tissues. During feeding, the seals may ingest sediments (directly or indirectly through their food) and the natural radionuclides contained in the sediments may have found their way to the organs of the animal.

Table 13: Average Radionuclide Activities in the U.S. Coastal Biota
(10^{-3}xBq/kg d.w. except for ^{40}K Bq/kg d.w.)

	^{40}K	^{90}Sr	^{137}Cs	^{238}Pu	Pu°	^{241}Am
NS&T 1990 Invertebrate Data*						
East	300±90	200±250	140±60	6±6	16±16	6±3
Gulf	330±90	130±140	64±40	14±25	24±36	11±14
West	280±40	170±470	250±100	3±3	12±8	36±31
Total	290±70	180±360	200±100	6±11	15±17	22±27
EPA 1977 Invertebrate Data**						
East	-	-	630±340	1.3±0.7	34±18	9±6
Gulf	-	-	550±900	2.2±2.2	25±22	4±2
West	-	-	400±220	1.3±0.7	33±24	63±70
Total	-	-	540±270	1.4±1.1	32±22	36±60
West Beaufort Invertebrate Data						
Arct. AK.	240±45	ND	700±300	ND	50±40	ND
West Beaufort Vertebrate Data						
Arct. AK.	161±142	40±20	250±210	ND	ND	ND

*After Valette-Silver and Lauenstein, 1995; ** After Goldberg *et al.*, 1983; $Pu^{\circ} = {}^{239+240}Pu$; -: not analyzed; ND= below detection limits.

•Artificial radionuclides

Artificial radionuclides in the marine invertebrates displayed a wide range of activities. The sipunculans (active burrowers) from Station B4 and the crinoids (suspension feeders) from Station E7 contained the highest activities for ^{137}Cs and $^{239+240}Pu$, respectively (Appendix A2). That situation could arise from the close physical contact of the animals with the sediments (burrows and feeding). The west Beaufort Sea activities were generally similar (Table 13) to those found in the coastal United States (Valette-Silver and Lauenstein, 1995; Goldberg *et al.*, 1983). In particular, ^{90}Sr and ^{241}Am were generally lower in both vertebrates and invertebrates in the western Beaufort Sea than in the rest of the U.S.

In contrast, ^{137}Cs and $^{239+240}Pu$ were usually several times more concentrated in the Beaufort marine invertebrates than in the rest of the U.S. (Valette-Silver and Lauenstein, 1995). In fact, the ^{137}Cs activities measured in our study in northern Alaska were very similar to or even higher than those measured twenty years ago in the coastal U.S. (Valette-Silver and Lauenstein, 1995; Goldberg *et al.*, 1983). As we inferred for ^{137}Cs activities measured in the sediments, this situation could arise from an input of ^{137}Cs coming from the Chernobyl accident (Aarkrog, 1988; 1989), the nuclear weapons testing fallout (Cambray and Eakins, 1980; Cawse and Horrill, 1986), and/or land-based contaminations (Cooper *et al.*, 1995a).

Analysis of North Atlantic invertebrates (Livingston and Bowen, 1975) shows also that echinoderms generally concentrate more plutonium (5.5 Bq/kg ^{239}Pu in starfish) and americium (0.78 Bq/kg ^{241}Am in sea urchins) than other groups of invertebrates do (0.26 Bq/kg in mussels). However, these values are about two orders of magnitude higher than those measured in west Beaufort Sea reflecting the contamination of the North Atlantic waters by the effluents of the Sellafield reprocessing plant. In areas where local contamination has been detected, such as the Neuse River estuary in the U.S. (Wolfe and Schelske, 1969; Wolfe, 1971; Schelske *et al.*, 1973), the Rhone River estuary in France (Gontier *et al.*, 1992), and the area close to Thule in Greenland (Aarkrog, 1971), artificial radionuclides in marine invertebrates were generally at higher concentrations than those measured in the Beaufort Sea. For example, ^{137}Cs activities in mussels reached 11.4 Bq/kg in the Neuse river, 8.8 Bq/kg in the Rhone River, and the median for ^{239}Pu activities reached 27.8 Bq/kg in bivalves and 274 Bq/kg in starfish from the Thule area. Some of these values are one to two orders of magnitude higher than those measured in the Polar Star samples. In the Kara and Barents Seas, which have been impacted by Russian nuclear testing and dumping and by the effluents from Sellafield, ^{137}Cs in marine invertebrates ranged from <0.57 Bq/kg in ophiuroideans (Strand *et al.*, 1993) to 17 Bq/kg in polychaetes (Matishov *et al.*, 1995). These values are of the same order or higher than the ^{137}Cs activities measured for west Beaufort Sea invertebrates. In the same samples (Strand *et al.*, 1993), activities of $^{239+240}Pu$ were also in the same range or higher than those measured in our Beaufort Sea samples. Finally, ^{90}Sr activities in asteroideans (0.07 Bq/kg) and ophiuroideans (0.11 Bq/kg) in the Barents/Kara Seas (Kuznetsov and Legin, 1993; Kuznetsov *et al.*, 1993) area were higher than in our samples.

In all these studies, as was observed for our own samples, it was found that animals feeding or living in close contact with fine sediments were enriched in artificial radionuclides.

•Less data exist for vertebrates, but ^{239}Pu concentrations as much as 3 to 4 orders of magnitude greater than those measured in northern Alaska were found in impacted areas such as the Thule area of Greenland (Aarkrog, 1971). For ^{137}Cs activities, our results were similar or lower than those measured in the Antarctic (Roos *et al.*, 1993) for seals (0.3 to 2.5 Bq/kg), fish (0.7 to 4.1 Bq/kg), and birds (0.2 Bq/kg).

2) Origin of the Artificial Radionuclides in the Western Beaufort Sea

As we have seen above, artificial radionuclides in the environment result from human activities, including among others: fallout, effluents from plutonium reprocessing plants, and activities of the former Soviet Union. Each source of contamination has its specific signature that can be seen in typical values of isotopic ratios (Hameedi *et al.*, 1995). In order to evaluate the role of these various sources in the artificial radioactivity observed in the western Beaufort Sea, ratios of artificial radionuclides were calculated for the sediments and, when possible, for the biota (Table 14).

***$^{240}Pu/^{239}Pu$**

•The average value of the $^{240}Pu/^{239}Pu$ ratio found for the Polar Star sediments collected in western Beaufort Sea was 0.189±0.019 (Table 14). This is very similar to the value recently measured elsewhere in the Arctic Basin (0.1853± 0.0053; Beasley *et al.*, 1995a; 1995b). Around the world, $^{240}Pu/^{239}Pu$ ratios in global fallout range from 0.12 to 0.21, with an average value of about 0.176±0.014 for the Northern Hemisphere (Krey *et al.*, 1993). Our results are very similar; thus in our samples these two plutonium isotopes appear to have originated from global fallout.

•No data are available for the biota, as these radionuclides were generally below detection in the biota.

***$^{241}Am/^{239+240}Pu$**

•In Chernaya Bay of Novaya Zemlya (Kara Sea), the location where some of the Former USSR nuclear testing took place in the 1950's, the sediments are contaminated with high activities of plutonium and are characterized by a $^{241}Am/^{239+240}Pu$ ratio of 0.05 (Smith *et al.*, 1995a; 1995b; Matishov *et al.*, 1995). This ratio is significantly lower than the ratio measured (0.30) for modern sediments

contaminated only by atmospheric fallout (Forman *et al.*, 1994; 1995; Smith *et al.*, 1995a; 1995b; Matishov *et al.*, 1995). For example, in sediments from the North-East Atlantic, this ratio ranges from 0.29 to 0.32 (Livingston and Bowen, 1976) and in Antarctic lake sediments it ranges from 0.31 to 0.72 (Roos *et al.*, 1993). The $^{241}Am/^{239+240}Pu$ ratio in the sediments collected by the Polar Star in the west Beaufort Sea averaged ~0.54±0.27 (n = 5). This ratio is of the same order of magnitude as that of fallout contaminated sediments and is higher than in the highly contaminated Chernaya Bay sediments.

•No data are available for the biota samples, because both of the radionuclides were generally below detection.

Table 14: Average Radionuclide Ratios in Sediments and Biota of the Western Beaufort Sea

	SEDIMENTS				
Station	**240/239**	**Am/Pu°**	**Cs/Pu°**	**Pu°/Cs**	**Cs/Sr**
B1	0.17	0.50	19.3	0.052	
B4	0.18	0.32	13.2	0.076	18.8
C1	0.20		64	0.016	
C3	0.19		75	0.013	
D1	0.19				
E1	0.18				
E5	0.19				16.2
E7	0.18		23.9	0.042	
E12	0.24	1	34.4	0.029	
E12	0.20	0.37	16.3	0.061	
E12	0.17	0.50	22.1	0.045	
G11	0.18		30.4	0.033	
Mean	0.19	0.54	33.2	0.041	17.5
Std	0.02	0.27	21.8	0.02	1.8

	BIOTA		
Station	**Cs/Pu°**	**Pu°/Cs**	**Cs/Sr**
E7 Crinoids	8.8	0.114	
G1 Spider Crab	25	0.040	
Bh Wh lung			0.4
Bh Wh liver			8.8
Kg Eider mus			6
Mean	16.9	0.077	5.1
Std	11.5	0.040	4.3

Pu° = $^{239+240}Pu$; 239 = ^{239}Pu; 240 = ^{240}Pu; Ratios of activities in Bq/kg d.w.
Spid. Crab = Spider crab; Bh Wh lung = Bowhead whale lung; Bh Wh liver = Bowhead whale liver; Kg Eider Mus = King eider muscle; Std = Standard deviation

*$^{239+240}$Pu /^{137}Cs

•The $^{239+240}$Pu /^{137}Cs ratio in global fallout was about 0.015 (Hardy, 1974) in the early 1970s. By the year 2004, this ratio should have almost doubled, due to the more rapid decay of ^{137}Cs (T = 30 years). This is very similar to the ratio measured in our study (0.041±0.02).

This same ratio averaged 0.015 in sediments from the Ob, the Yenisey, and Kara Sea (Baskaran *et al.*, 1995a, 1995b, 1995c; Livingston and Sayles, 1994, 1995) and ranged from 0.016 to 0.063 in Antarctic lake sediments (Roos *et al.*, 1993). It was also shown that this ratio increases with the salinity of the environment (Olsen *et al.*, 1981). In studies of Kara Sea sediments, this ratio ranged from 0.021 to 0.148 (Strand *et al.*, 1993).

The reverse ratio (^{137}Cs/$^{239+240}$Pu) was calculated by Krey *et al.* (1976) for reservoir sediments collected in Utah. This ratio ranged from 24 to 49 in sediments contaminated only by global fallout. In our sediments, this ratio averaged 33.18±21.77, similar to the value found in sediments impacted by global fallout (Forman *et al.*, 1995). This is very different from the ratio measured in the highly contaminated sediments of Chernaya Bay in the Barents Sea, where this ratio is very low (ranging from 0.013 to 0.056), indicating a much higher input of Pu (Forman *et al.*, 1995).

•In the Polar Star biota, the $^{239+240}$Pu/^{137}Cs ratio was only measurable in invertebrates and ranged from 0.04 to 0.114 (average 0.077±0.040; n = 2). These values are similar to those measured in bivalves collected around the United States (ratio ranging from 0.01 to 0.14; Valette-Silver and Lauenstein, 1995) in areas only affected by global fallout.

In the Polar Star biota, the reverse ratio ^{137}Cs/$^{239+240}$Pu averaged 16.9±11.5. These values are very similar to the results obtained by Noshkin *et al.* (1971; Noshkin and Bowen, 1972) for fallout impacted clams and blue mussels, for which this ratio ranged between 15 and 27.

*^{137}Cs/^{90}Sr

•The ratio ^{137}Cs / ^{90}Sr in the western Beaufort Sea sediments ranges from 16.2 to 18.8 (average 7.5±1.8; n = 2). This ratio is equal to 1.5 (Hviden and Lillegraven, 1961; Hardy, 1974) in sediments affected by global fallout. Beaufort Sea values are about one order of magnitude greater than the fallout value and could be interpreted as reflecting either an input of non-fallout ^{137}Cs in this area, hypothesis already raised for another ratio, or by an abnormally low ^{90}Sr in that fallout. Studies

have shown that in Nordic regions impacted by the Chernobyl accident, this ratio has been modified (Salo and Voipio, 1966; White *et al.*, 1986; Goldman, 1987; Aarkrog, A., 1988; 1889; Baskaran *et al.*, 1991). In the fallout from this accident, deposition of ^{90}Sr was one order of magnitude less than deposition of ^{137}Cs giving rise to a higher Cs/Sr ratio. This could explain what we are observing in the Polar Star samples.

•In the west Beaufort Sea, because of the low activities of ^{137}Cs and ^{90}Sr (often not detected), the ratio of these two radionuclides was not calculated for invertebrates. It was measurable only for vertebrates and averaged 5.07±4.28, a value which is also higher than the ratio expected from global fallout (global fallout value = 1.5; Salo and Voipio, 1966). The $^{137}Cs/^{90}Sr$ ratio measured in invertebrate samples collected in the coastal United States (Valette-Silver and Lauenstein, 1995) is highly variable, ranging from 0.35 to 14.79.

***Summary**

In summary, most of the anthropogenic radionuclides found in the Polar Star sediment and biota samples appear to derive mainly from global fallout with perhaps a small input of ^{137}Cs due either to the Chernobyl accident or to local inputs. The activities of the anthropogenic radionuclides in Polar Star sediments and biological samples were very low compared to contaminated areas elsewhere, much below any dangerous level (for example, the maximum permissible human intake for ^{137}Cs is between 50, 000 and 100, 000 Bq/year for a human; Jones *et al.*, 1989; Baskaran *et al.*, 1991). Thus these levels do not appear to present any substantial danger to the Beaufort Sea ecosystem or to the inhabitants of northern Alaska .

B) Trace Metal

1) Sediments

In this section, when comparisons with literature values are made and no specific information was provided in the cited reference, we have assumed that literature data are not grain-size corrected and that they are expressed in ppm (or equivalent units) dry weight.

The Polar Star data (raw and grain size corrected) showed that trace metal concentrations in sediments from the Beaufort Sea (Tables 5, 10, 15), except for arsenic, manganese, and maybe antimony and zinc, were comparable to those found in crustal rocks (Turekian, 1971; Drever, 1982; Boehm *et al.* , 1990).

Compared to the NS&T Alaskan data set (raw and grain size corrected), the mean concentrations of the raw data (Table 5, 10, 15) as well as the grain size-corrected mean concentrations measured in our study are either on the same order or lower. The only exceptions are for As and Mn which are respectively 4 to 6 times and 2 to 5 times higher in the present study than in the NS&T Alaskan results.

Except for As and Ni, the concentration of metals in Polar Star sediments are lower than the NS&T national average of metals in sediments collected around the United States (O'Connor, 1991a).

Table 15: Average Trace Metal Concentrations in Polar Star and NS&T Sediments (ppm d.w.)

	Ag	AgCor*	As	AsCor	Cd	CdCor	Cr	CrCor
Polar	0.07	0.09	34	38	0.12	0.14	92	103
NST AK.	0.2	0.34	5.4	9.6	0.38	0.91	88	237
NST Av°		0.35		13		0.48		110
Crust**	0.04 to 0.1		1 to 13		0.13 to 0.2		10 to 170	

	Cu	CuCor	Fe•	FeCor•	Hg	HgCor	Mn•	MnCor•
Polar	35	37	4.37	4.80	0.071	0.079	0.38	0.40
NS&T AK.	29	52	4.13	12.01	0.1	0.2	0.08	0.24
NST Av°		35				0.17		
Crust**	2 to 87		4.1		0.01 to 0.40		50 to 1500	

	Ni	NiCor	Pb	PbCor	Sb	SbCor	Se	SeCor
Polar	47	50	20	21	1.37	1.54	0.26	0.28
NS&T AK	21	42	20	38	1.07	2.20	0.39	0.65
NST Av°		34		43				
Crust**	2 to 130		6 to 20		0.1 to 1		0.05 to 0.9	

	Si•	SiCor•	Sn	SnCor	Zn	ZnCor
Polar	26.6	29.7	2.4	2.6	116	127
NS&T AK.	27.3	58.7	2.0	6.4	118	264
NST Av°				3.2		140
Crust**					16 to 105	

* Grain size corrected values, ** Average crustal value after Turekian, 1971; Drever 1982; Boehm *et al.*, 1990.
°O'Connor, 1988; 1990; 1991a. •Concentrations expressed in %.

Compared to the results of studies performed in the Beaufort Sea by other authors (Barnes, 1974; Naidu and Mowatt , 1974; Crecelius *et al.*, 1990; Boehm *et al.*, 1990), the Polar Star sediment results are slightly higher for some of the metals, such

as As or Cd (Table 16). In these previous studies, it has been shown that the variations in metal concentrations were mostly related to grain-size variations of the sediments, higher concentrations being measured in fine-grained sediments rich in organic matter and iron. This may explain the slight differences observed in our own samples.

Table 16: Average Trace Metal Concentration in Beaufort Sea Sediments (ppm d.w.)

	As	Cd	Cr	Cu	Fe°	Hg	Pb	Zn
1*		0.14	48	17			8.5	62
2**	19(6-60)			19.1		0.040	12.4	87.3
3†		0.16	96	23	3.4		1	109
4‡				31-59	2.1-3.6			
Polar:								
NC	29(10-43)	0.15	87	35(11-63)	4.4(2.6-5.2)	0.076	19	121
C	32(14-58)	0.16	97	37(17-63)	4.8(4.1-5.4)	0.083	20	131

°Fe in %;
*After Crecelius *et al.*, 1990;**After Barnes, 1974; †After Boehm *et al* ., 1990,
‡Naidu and Mowatt, 1974. NC = not corrected for grain size; C = corrected for grain size.

Table 17: Trace Metal Concentrations in Arctic Sediments (ppm d.w.)

	As	Cd	Cu	Hg	Pb	Zn
Polar NC	29	0.15	35	0.076	19	121
Polar C	32	0.16	37	0.083	20	131
1	-	0.11	30	0.06	22	57
2	-	0.32	12.5	0.03	12.4	73.8
3	-	0.09	31.2	0.165	24.5	111.3
4	-	0.12	11	0.031	12	25
5	-	0.12	17	0.054	18	65
6	69	0.13	22	-	25	93
7	61	0.12	26	-	18	92
8	113	0.07	21	-	19	80
9	53	0.09	26	-	17	84
10	36	0.12	25	-	19	83
11	21	0.11	45	-	15	108

(1) Baffin Bay, Loring, 1984; (2) Beaufort Sea, Thomas *et al.*, 1992; 1983; (3) Est Greenland, Dietz *et al.*, 1995; (4) Pechora Estuary, Rosgidromet, 1995; (5) Kara sea, Rosgidromet, 1995; (6)Svalbard Shelf, dos Santos *et al.*, 1995; (7) Frantz Josef Land, dos Santos *et al.*, 1995; (8)Pechora Sea, Loring *et al.*, 1995; (9) Kara Shelf, Loring *et al.*, 1997; (10) Ob Estuary, Loring *et al.*, 1997; (11) Yenisey Estuary, Loring *et al.*, 1997; NC = Value not corrected for grain size; C = Value corrected for grain size .

Only a few As data are available in the literature for Alaska or elsewhere in the Arctic (Svalbard Shelf, dos Santos *et al.*, 1995; Frantz Josef Land, dos Santos *et al.*, 1995; Pechora Sea, Loring *et al.*, 1995; Kara Shelf, Loring *et al.*, 1997; Ob Estuary, Loring *et al.*, 1997; Yenisey Estuary, Loring *et al.*, 1997). It is thus difficult to determine the origin of the elemental enrichment observed in our study (As averaged 29 ppm, uncorrected data) and in an earlier Beaufort Sea study (As ranged from 6 to 60 ppm; average = 19 ppm; n = 170; Barnes, 1974). It seems likely that this enrichment comes from the country rocks; however, because the average As concentration in the 1994 samples is almost twice the 1971 mean, the role of anthropogenic inputs cannot be completely excluded.

Except for Zn, which is often more concentrated in our samples, the Polar Star sediment trace metal concentrations are very similar to those reported from other areas in the Arctic (Table 17), such as the Canadian Arctic (Campbell and Yeats, 1982; Thomas, 1988; Thomas *et al.*, 1983; Loring, 1984; Boehm *et al.*, 1990), Greenland (Dietz *et al.*, 1985; dos Santos *et al.*, 1995), or the Russian Arctic (Rosgidromet, 1995; Loring *et al.*, 1995; 1997).

From these comparisons, it appears that most of the trace element concentrations measured in sediments are at levels consistent with erosion of the country rock. Only Zn is elevated in the Polar Star sediments and As is either in the same range or lower than most of the recent data produced for other areas of the Arctic (Table 17). These observations may be related either to the occurrence of ore deposits in the area and/or to human activities.

2)Biota

Trace metals were not analyzed in the biological samples collected during the Polar Star cruise. However, data are available from the NS&T program in Alaska (Table 10; 18) for mollusks collected for the Mussel Watch Project in subarctic Alaska and fish livers collected for the National Benthic Surveillance Project in Alaskan waters with two sites located in the Beaufort Sea.

For the biological samples, all the comparisons are based on data expressed in µg/g dry weight. When the literature results were expressed in µg/g wet weight, we converted the data assuming that dry weight represents about 10% of the tissue wet weight. A study by Feder *et al.* (1991) calculated the conversion factors among wet weight, organic carbon content, and dry weight for over two hundred types of organisms. From this study, the conversion factor between wet weight and dry weight ranges from 2% to about 20% with an average around 13%. In addition, data from the

NS&T Mussel Watch Project show that the dry weight of mussel and oyster soft tissues is about 10% of their wet weight. Finally, when no detail was given in the literature, we assumed that, for the bivalves, the data referred to soft tissue analyses. Regarding the fish analyses, when no information was given in the literature, we assumed that the analyses referred to the whole body.

Table 18: Trace Metal Concentrations in Alaska and Arctic Biota (µg/g d.w.)

A-Invertebrates

	Cd	Cr	Cu	Hg	Pb	Se	Zn
NS&T Alaska:							
Mollusks* Av.	2.8	3.4	10.3	0.08	1.24	3.94	89
Beaufort Sea:							
1-Astarte	13	1.8	17	-	0.6	-	90
1-Cyrtodaria	2.8	3	21	-	0.6	-	80
1-Portlandia	6	8	16	-	2.3	-	148
1-Macoma	6	9	28	-	1.0	-	204
Arctic:							
2-Greenland*	11.1	-	-	0.16	1.0	7.2	-
3-Greenland*	5.8	-	-	0.16	12.0	9.4	-
4-Iceland*	6.3	-	-	0.90	5.6	-	-
5-Canada**	2.1	-		0.07	1.5	-	-
6-Russia***	87	-	-	0.22	10	-	-

B-Fish livers

	Cd	Cr	Cu	Hg	Pb	Se	Zn
NS&T:							
†Alaska° Av.	1.10	0.36	18.0	0.19	0.63	10.0	104
†Beaufort° Av.	0.55	0.40	5.1	0.33	0.03	5.7	106
Arctic:							
7-†Canada°	5	-	-	0.3	-	16.1	-
8-†Iceland°°	2.6	-	-	-	0.18	11.9	-
9-†Norway°°	0.62	-	-	-	0.15	17.0	-
10-†Russia°°	4.9	-	-	-	0.62	17.0	-

(1) Boehm *et al.*, 1990; (2) and (3) Riget *et al.*, 1995; (4) Olafson, 1986; (5) Wagemann & Stewart, 1994; (6) Rosgidromet, 1995; (7) Muir *et al.*, 1992; (8) Stange *et al.*, 1996; (9)and (10) Maage *et al.*, 1996 (in press).
* Blue mussels;** Clams; ***Cockles;° Flounder (*Platichthys*); °°Flathead sole (*Hyppoglossoides).* †Liver data

Comparison of the results (Tables 10, 18 and Appendix A9) obtained for the mollusks collected in Alaska by the NS&T Program with other Arctic data shows that the concentrations found by the NS&T Program are in general either lower than or

about the same as those found in mollusks from other areas. This may be related to a difference in the nature of country rocks and/or to a lower anthropogenic pollution in northern Alaska.

Table 19: Average Organic Compound Concentrations* in Polar Star and Other NS&T Sediments (ng/g d.w.)

	SEDIMENTS*					
PAHs	**tNaph**	**tFluor**	**tPhen**	**tDiben**	**tChry**	**tPAHs**
Polar Star Av.	173	8	182	44	57	567
NST Beauf. Av.	194	8.67	107	17	16	508
NST Rest AK Av.	13	10	44	0	64	226
NST tAK Av.	86	9.33	62	17	45	289
NST Natl Av.**						740

Organochlorines	**Hexachlor**	**Lindane**	**Mirex**	**tCdane**	**tDield**	**tDDT**
Polar Star Av.	ND	0.17	ND	0.20	0.22	0.44
NST Beauf. Av.	0.28	0.20	0.06	ND	ND	0.17
NST Rest AK Av.	0.38	0.60	ND	0.16	ND	1.71
NST tAK Av.	0.35	0.54	0.06	0.16	ND	1.52
NST Natl Av.**				3.2		6.6

Organochlorines	**tPCBs**	**tPCB Congs**
Polar Star Av.	≈4.5	1.18
NST Beauf. Av.	31.7	5.65
NST Rest AK Av.	18.8	7.32
NST tAK Av.	20.8	6.66
NST Natl Av.**	≈82.4	39

*Values corrected for grain size; NST Beauf Av: NS&T Beaufort Sea sites average; NST Rest AK Av.: NS&T Alaska sites excluding Beaufort Sea sites average; NST tAK Av.: NS&T all Alaskan sites average; NST Natl Av.: NS&T all sites from the coastal US. †tPCBs is about equal to twice the tPCB congeners (18 congeners that are measured as part of the NS&T); for sediments ΣPCBs = 2.05(Σcongeners)+2.4 as defined by GERG);**O'Connor, 1991a; 1991b; 1992; 1997 pers. com.

Comparison of the results (Table 10; 18; Appendix A9) obtained for fish collected at the NS&T Benthic Surveillance sites (BEAOP and BEAPB) located in the Beaufort Sea to the rest of the NS&T Alaskan data shows that Hg, Mn, and Ni are slightly enriched (about twice the concentrations) in the Beaufort Sea fish livers. Comparison to other Arctic data (Tables 10, 18, A9) obtained for four metals (Cd, Hg, Se, and Zn) in similar types of fish (*Hyppoglossoides* or *Platichthys*) captured in the Canadian Arctic (Bohn and McElroy, 1976; Bohn and Fallis, 1978; Fallis, 1982; MacDonald, 1986; MacDonald and Sprague, 1988; Muir *et al.*, 1987; Muir *et al.*, 1992), in Europe (Carlberg and Boler, 1985; Dietz *et al.*, 1995; Stange *et al.*, 1996), and in the Russian Arctic (Maage *et al.*, 1996) shows that NS&T Beaufort Sea data are on the same order or lower than data from other Arctic areas. This may be related to

differences in country rocks composition and to the more pristine state of the U.S. Arctic.

C) Organic compounds

1)Sediments

All the sediment data are presented in ng/g dry weight. For data from the literature, if no information is provided, it is assumed that they are raw data, uncorrected for grain size, and expressed in ng/g (or equivalent units) dry weight.

*PAHS

The grain-size corrected PAH concentrations in sediment samples from the Polar Star Cruise (Tables 11, 19; Appendices A4, A12) are similar to the sediment PAH concentrations from other NS&T sites in Alaska. Excluding sites B1 and G11 where the sediments were very coarse, the PAH concentrations showed a moderate positive correlation with the grain size of the sediments (tPAHs/grain size r = 0.69).

Table 20: PAHs Concentrations in Arctic Sediments (ng/g d.w.)

	1	**2**	**3**	**4**	**5**	**6**
BaP	0.6-10.1	2.2-33.1	0.7-24.3	1.6-13.4	0.4	6-134
	Polar Star					
BaP	0.74-8.72					
	7	**8**	**9**	**10**	**11**	**12**
tPAHs	94-8222	6.7-933	50-4094	20-1358	16.8-1119	866
	13	**14**	**15**	**16**	**17**	**18**
tPAHs	97-1341	0.4-20	68-1856	20-380	23-6785	5.7-13
	19	**Polar Star**				
tPAHs	ND-810	159-1092				

BAP = Benzo(a)pyrene; tPAHs = total polyaromatic hydrocarbons; 1: Beaufort Sea, 2: Mackenzie Delta, 3: Kittigazuit Bay, 4: Smoking Hills, 5: Devon Island, all after Stich and Dunn, 1980; 6: Issungnak, Erickson *et al.*, 1983; 7: Tuktoyaktuk Harbour, 8: McKinley Bay, 9: Beaufort Sea, Thomas *et al.*, 1982; 10: Yukon coast, CanTest, 1985; 11: Huchinson Bay, 12: South Beaufort Sea, Thomas *et al.*, 1982; 13: South Beaufort Sea(marine), 14: South Beaufort Sea (coastal), Wong *et al.*, 1976; 15: South Beaufort Sea, Erickson *et al.*, 1983; 16: Beaufort Sea (coastal), Boehm *et al.*, 1986; 17: South Beaufort Sea, Fowler and Hope, 1984; 18: Baffin Island, Cretney *et al.*, 1987a, 1987b, 1987c; 19: Pechora and Kara Sea, Brooks *et al.*, 1994; 1995).

PAH concentrations showed low correlations with the concentrations of total organic carbon (TOC) in the sediments as did the total inorganic carbon (TIC) content.

A comparison of the Polar Star results with previous NS&T data (Table 11, 19 and Appendices A4 and A12) shows that among the PAHs, acenaphthene, acenaphthylene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, benzo(a)pyrene, benzo(ghi)pyrene, chrysene, indenopyrene, and tPAHs are generally lower in the western Beaufort Sea than in the rest of Alaska. All the other compounds are higher in our study than in the rest of Alaska. The averages for sedimentary tPAHs in NS&T samples collected in Alaska and specifically for those collected in the Beaufort Sea (averages 247 and 526 ng/g respectively) are lower than the tPAHs average for samples collected in the rest of the coastal U.S. (average of 740 ng/g).

Table 21: Average PAHs Concentrations* in Beaufort Sea Sediments

(ng/g d.w.)

	Naph	2-MNaph	1-MNaph	BPH	2, 6-DMNaph
OCSEAP*	t-2.0	6.9-11.5	5.7-7.9	2.4-3.2	9.0
Polar Star**	14.3	35.2	26.1	9.5	26
	DMNaph	**TMNaph**	**Flu**	**Dibenz**	**Phn**
OCSEAP	12.9	-	1.7-8.1	6.0	31.3-32.9
Polar Star	-	14.8	6.7	4.9	31.4
	MPh	**Ant**	**Fla**	**Pyr**	**BaA**
OCSEAP	78-86.6	t	12.2-23.1	16.5-25.7	-
Polar Star	10.8	11.0	5.1	7.0	2.7
	Chr	**BeP**	**BaP**	**Per**	
OCSEAP	21.2-28.6	t	t	10.0-40.8	
Polar Star	13.6	10.0	2.6	20.5	

*values not corrected for grain size.
Naph: Naphthalene; 2-MNaph: 2-Methylnaphthalene;1-MNaph: 1-Methylnaphthalene; BPH: Biphenyl; 2, 6DMNaph: 2, 6-Dimethylnaphthalene; DMNaph: Dimethylnaphthalenes; TMNaph: Trimethylnaphthalenes; Flu: Fluorene; Dibenz: Dibenzothiophene; Phn: Phenanthrene; MPh: Methylphenanthrenes; Ant: Anthracene; Fla: Fluoranthene; Pyr: Pyrene; BaA: Benz[a]anthracene; Chr: Chrysene; BeP: Benz[e]pyrene; BaP: Benz[a]pyrene; Per: Perylene; t: traces; OCSEAP*: Range of values obtained in the Outer Continental Shelf Environmental Assessment Program in Beaufort Sea (Kaplan and Venkatesan, 1985).; Polar Star**: Average concentrations of raw values.

Comparison of our data for benzo[a]pyrene as well as for tPAHs with results published in the literature for other Arctic areas (Table 20) shows similar values (Wong *et al.*, 1976; Stich and Dunn, 1980; Thomas *et al.*, 1982; Erickson *et al.*, 1983; Fowler *et al.*, 1984; CanTest, 1985; Boehm *et al.*, 1986; Cretney *et al.*, 1987 a, 1987 b, 1987c;

Brooks *et al.*, 1994; 1995). However, it is sometimes difficult to compare tPAHs values because this term does not always cover the same sum of compounds.

A detailed study of the Alaskan continental shelf (Outer Continental Shelf Environmental Program - OCSEAP) was previously conducted by NOAA during the 1975-1990 period (Table 21). Compared to OCSEAP results from the Beaufort Sea, the Polar Star sediments appear to have a slightly different PAHs composition. For example, concentrations of most of the naphthalenes, anthracene, benzo[e]pyrene and perylene are higher in our study than in OCSEAP results. On the contrary, methylphenanthrene, fluoranthene, pyrene, and chrysene are lower in the Polar Star data. These two sets of data were produced in 1981 and in 1995 respectively, and the differences observed could be real, due to change in the composition and the amount of PAHs in the Alaskan Arctic over time.

However, it is difficult to compare accurately data produced more than 15 years apart, and the differences observed could mainly be due to differences in analytical techniques and precision and/or to differences in the locations sampled.

The results of the OCSEAP region-wide survey have been reported by Venkatesan and Kaplan (1982) and Kaplan and Venkatesan (1985). We assumed that their data were reported for dry sediments, uncorrected for grain size. The salient point of these studies indicated that at the time of this study and in light of the ubiquitous nature of hydrocarbons and of varied and often unavoidable sources of petroleum contamination, Alaskan continental shelf areas were generally considered as pristine.

Table 22: Diagnostic PAHs Ratios in Polar Star Sediments

Station	B1	B4	C1	C3	D1	E1	E5	E7	E12	G11	Aver.
N/P*	1.17	0.83	0.66	0.69	0.66	0.86	0.96	6.5	0.93	1.12	0.93
FFPI**	0.62	0.66	0.70	0.67	0.73	0.71	0.75	0.63	0.65	0.69	0.71

*N/P = Ratio of naphthalene/phenanthrene. In pristine regions, this ratio is low (<1), and much larger for petroleum. For Prudhoe Bay crude oil, this ratio is = 4.0. **FFPI = Fossil fuel pollution index = (N+F+P+D)/ΣPAH; N = naphthalene series; F = fluorene series; P = phenanthrene/anthracene series; D = Dibenzothiophene series. This index ranges from 1 for fossil fuel PAHs (e.g., Prudhoe Bay crude oil) to nearly 0 for combustion PAHs.

Hydrocarbon concentrations in sediments of the U.S. Arctic were as low or lower than those expected in uncontaminated coastal areas and deep basins (usually below 70 μg/g; Clarke and MacLeod, 1977) and considering our most recent data (about 1 μg/g tPAHs), this still holds true for the western part of the Beaufort Sea where the Polar Star samples were collected .

In the OCSEAP study (Kaplan and Venkatesan, 1985), the analysis of specific compounds, not analyzed in our study, showed that the sediments of the area are a mixture of marine autochthonous and terrestrial allochthonous hydrocarbons. In particular, the predominance of odd-carbon number n-alkanes and maxima at C_{27} and C_{29} alkanes, such as heptacosane (derived from vascular plants), suggested the influx of detrital material from several rivers that empty into the Bering and the Beaufort Seas. In many of their samples, marine biogenic origin was also indicated by the dominance of heptadecane and pristane (which are derived from marine plankton). A general absence of unresolved complex mixtures, and high values of the pristane-phytane ratio (1.5 to 2.5) also indicated that anthropogenic sources of hydrocarbons were minimal. Pr/Ph ratios of ~1 are often inferred to be an indicator of petroleum pollution and the presence of phytane could result from bacterial activity (Tissier and Oudin, 1973).

In our study, diagnostic ratios do not suggest crude oil as a significant source of PAHs. However, the presence of a well represented naphthalene series in our samples shows that crude oil, possibly from Prudhoe Bay, is present. In addition to crude oil, the relative amounts of PAHs indicate pyrolitic and fossil sources. Forest fires along the Beaufort Sea coast are highly improbable due to the scarcity of forests in the area. However, if direct input from lower latitudes fires is probably very small (Laflamme and Hites, 1978), long-range atmospheric transport and deposition of pyrolitic compounds has been recognized as a potentially important source of anthropogenic PAHs in the Beaufort Sea coastal sediments. Perylene, which is of natural origin, has been detected in most samples. It is noteworthy that neither chrysenes nor perylene is found in Prudhoe Bay crude oil in any significant amount. However, the mode of formation of perylene is not absolutely clear (Kaplan and Venkatesan, 1985) and may be derived either from terrestrial or marine sources.

In summary, possible sources of PAHs in the region include outflow from rivers, peat from eroded coastline, oil seeps, Prudhoe Bay oil fields, diagenesis, and long-range atmospheric transport.

Finally, all the data reported for the PAHs in the Polar Star sediments appear in general to be too low to be a major problem for the environment, since all of our data

are below ER-L (4000 ng/g) and ER-M (45, 000 ng/g) values (Long and Morgan, 1990; Long *et al.*, 1995).

***PCBs**

Total PCBs were weakly correlated with the TOC and TIC contents of the sediments (r= 0.49 for TOC and r = 0.46 for TIC). The averages for total PCBs and for most of the PCBs congeners (except for PCB 8, 18, 66, 105, 187, 195, and 206) were lower in the Polar Star study than the comparable averages of the results obtained in the NS&T Program (for sites located around the U.S. and sites sampled in 1984 in the Beaufort sea -Table 19; Appendices A5, A10). This may be related to the fact that previously sampled sites were nearer shore than the Polar Star stations. It may also imply that since 1984, PCBs concentrations have decreased in the Beaufort Sea and the low concentrations measured in our study could be related to the 1970's PCBs ban and the general decrease of their concentrations in the environment. In addition, the tPCBs in sediments from the Polar Star are very low compared to the NS&T national average (4.5 versus 82 ng/g, respectively). This could be explained by the fact that the Alaskan Arctic has been less impacted by PCBs than other areas of the U.S.

Generally, PCB concentrations in the Arctic are about one to two orders of magnitude lower than what is found in sub-Arctic regions (O'Connor, 1991b; Muir *et al.*, 1992; Table 19). Very few data exist presently for other areas of the Arctic, but the existing data are similar to our results and generally point to very low concentrations of tPCBs. For example, Muir *et al.*, (1992) reported concentrations lower than 5.9 ng/g for sediment particles collected off Ice Island in Canada. Recent intensive investigations of the Russian Arctic seas and rivers should provide more results in a very short time-frame. For example, tPCB congeners (including the 18 congeners generally analyzed in the NS&T Program) in surficial sediments collected from the Pechora and Kara Seas and their adjacent rivers (Pechora, Ob, Yenisey Rivers) reach about 8.7 ppb (Brooks *et al.*, 1994; 1995), a value corresponding to about 20 ppb tPCBs. The average of these Russian concentrations is higher than what was found for the western Beaufort Sea during the Polar Star Cruise. In Antarctica, PCBs concentrations in sediments collected at remote sites are generally below 1 ng/g. Some slightly elevated values were detected in Arthur Harbor (2.8 to 4.2 ng/g), but exceptionally high concentrations were observed near McMurdo Station. In particular, in Winter Quarter's Bay, concentrations ranging from 250 to 4300 ng/g (d.w.) have been reported (Kennicutt, II *et al.*, 1995).

PCBs have been found in abundance in the snow packs of various Arctic countries (Barrie *et al.*, 1992). For example, concentrations as high as 2.5 ng/l have been reported in the Norwegian Sea ice (Gaul, 1992) and up to 1.78 ng/l in the Canadian Arctic (Gregor, 1989). Thus, besides the local anthropogenic inputs of PCBs to the Alaskan Arctic, atmospheric transport may then be a non-negligible source of these anthropogenic compounds.

Concerns about PCBs arise partially from the fact that most of the congeners, especially those with five or more chlorine atoms, are strongly biomagnified in the food chain. All the values recorded for the Polar Star sediments were below ER-L (22.5 ng/g) and ER-M (180 ng/g) values (Long and Morgan, 1990; Long *et al.*, 1995). However, the risks associated with the biomagnification of these compounds in the food chain and with the effects of planar PCBs on living organism are not well known (Muir *et al.*, 1988).

***Pesticides**

The concentrations of some of the measured pesticides, such as lindane, are quite highly correlated with TOC and TIC (r = 0.78 and 0.79 respectively) whereas others, such as tDDTs, are very weakly and inversely correlated with TOC (r = -0.30) and TIC (r = -0.35). Consequently when all the pesticides are combined (r = -0.22 with TOC, r = - 019 with TIC) no correlation is evident.

As was shown in the results section (Table 11; Appendices A6, A7, A11 and A14), most of the samples collected for this study were devoid of detectable amounts of organochlorine contaminants. Among the pesticides, hexachlorobenzene and lindane were lower in the Polar Star samples than in any NS&T data (including national and Alaskan averages), and cis-chlordanes and dieldrin were slightly higher in the new samples than in the previous Alaskan data. Average total DDTs were higher in the Polar Star samples than in the NS&T Beaufort Sea sediments but were still lower than the average obtained for the rest of Alaska and the coastal United States. In the previous NS&T study of the Beaufort Sea, 4, 4'-DDT had the highest concentration among the tDDTs components, whereas in the Polar Star study 2, 4'-DDE had the highest concentrations and the largest component. This appears to be correlated to the break-down of DDT into its metabolites over time. In surficial sediments from the Pechora and Kara Seas in the Russian Arctic and adjacent rivers, tDDTs and chlordane concentrations ranged from "not detected" to 1.2 ppb (Brooks *et al.*, 1995), concentrations that are higher than those found in the Alaskan Arctic in the present study.

Most of these organochlorines are found in measurable quantities in air, precipitation, and snowpack from all the Arctic area (Barrie *et al.*, 1992; Chernyak *et al.*, 1996). For example, Patton *et al.* (1989) measured DDT levels up to 5.2 pg/m^3 and tchlordane levels in air ranging from 2-10 pg/m^3, while Hargrave *et al.* (1988) measured tDDT = 20 pg/l in fresh spring snow from Ice Island (Canada). Hexachlorobenzene (up to 104 pg/l in the Canadian Arctic snowpack, Gregor, 1989; and up to 50 pg/l in the Norwegian sea ice, Gaul, 1992) and DDTs (up to 1380 pg/l in the Canadian Arctic snowpack, Gregor, 1989; and up to 250 pg/l in the Norwegian sea ice, Gaul, 1992) are several orders of magnitude more abundant in snowpack than in the Polar Star sediments. This observation demonstrates that, beside the direct input of the pesticides to the Arctic environment, large quantities may also be derived from atmospheric deposition.

As in the case of PCBs, concerns about the effects of pesticides in the Arctic arose from the fact that DDT compounds, in general, and DDE, in particular, are highly biomagnified in aquatic and terrestrial food chains. In addition, most of the chlorinated pesticides have a high lipophilicity and long half-lives in biota. In the Polar Star sediments, tDDTs concentrations were always below ER-L (1.58 ng/g) and ER-M (46.1 ng/g) values (Long and Morgan, 1990; Long *et al.*, 1995).

2)Biota

For the biological samples, all the comparisons are based on data expressed in ng/g dry weight. When the literature results were expressed in ng/g wet weight, we converted the data assuming that dry weight represents about 10% of the wet weight. When no information was given in the literature, we assumed that, for the bivalves, the data referred to analyses of tissues excluding shells. Regarding the fish analyses, when no information was given in the literature, we assumed whole body analyses.

* PAHs

The averages for t-phenanthrene/anthracenes and t-chrysenes were about one order of magnitude higher in the Polar Star marine invertebrates than in mussels from other NS&T samples from Alaska (Table 23).

The average for tPAHs was lower in Polar Star Beaufort Sea invertebrates than in mollusks from the NS&T samples from the rest of Alaska and from the rest of the United States (Table 23, Appendices A6; A15).

In a study performed by Boehm *et al.* (1985, 1986, 1990) in the Beaufort Sea, the PAHs were also low, ranging from below detection to 2400 ng/g d.w. depending on proximity to the Prudhoe oil fields and the MacKenzie River delta.

Table 23: Average Organic Compound Concentrations* in Polar Star and Other NS&T Biota (ng/g d.w.)

INVERTEBRATES

PAHs	Tnaph	Tfluor	Tphen	Tdiben	Tchry	TPAHs
Polar Star Av.	25.8±13.8	6.84	11.6±10.3	ND	17±21	67.3±52
NST Beauf. Av	-	-	-	-	-	-
NST AK Av.	84±35	1.65±0.96	15.3±10.6	ND	9.0±11.70	188±41
NST Natl Av.**						290

Organochlorines	Hexachlor	Lindane	Mirex	TCdane	tDield	tDDT
Polar Star Av.	2.7±3.8	1.65±1	0.46	2.51±1	2.76±3.8	0.74±0.7
NST Beauf. Av.	-	-	-	-	-	-
NST AK Av.	0.56±0.11	ND	ND	1.48±0.69	0.57±o.31	1.60±0.36
NST Natl Av.**				14	4.9	38

Organochlorines	tPCBs	tPCB Congs
Polar Star Av.	≈29.6†	12.2±9
NST Beauf. Av.	-	-
NST AK Av.	42.3±9.4	2.21±1.95
NST Natl Av.**	120	

VERTEBRATES

PAHs	Tnaph	Tfluor	Tph/an	Tdiben	Tchry	TPAHs
Polar Star Av.°	19.9	ND	ND	ND	ND	19.9
NST Beauf. Av.	-	-	-	-	-	-
NST AK Av.	-	-	-	-	-	-

Organochlorines	Hexachlor	Lindane	Mirex	TCdane	tDield	tDDT
Polar Star Av.	4.92	0.86	ND	7.95	1.49	3.22
NST Beauf. Av.°	34.7±11.2	3.13±2.2	1.52±0.45	37.1±2.7	14.17±1.65	36.6±10
NST AK Av.°°	13.6±12.7	2.8±1.7	2.02±0.81	40.4±17.7	7.65±5.24	109±85

Organochlorines	tPCBs	tPCB Congs
Polar Star Av.	≈20.4†	7.97
NST Beauf. Av.	602±551	
NST AK Av.°°	587±585	
NST Natl Av.	2191±4328	

NST Beauf Av.: NS&T Beaufort Sea sites average; NST Rest AK Av.: NS&T Alaska sites excluding Beaufort Sea sites average; NST tAK Av.: NS&T all Alaskan sites average; NST Natl Av.: NS&T all sites from the coastal US. °Sculpin; °°Flathead sole; †tPCBs is about equal to twice the tPCB congeners, for bivalves Texas A&M calculated ΣPCBs = 2.2(Σcongeners)+2.8);**O'Connor, 1991;O'Connor, 1996.

It is interesting to note that accumulation of PAHs in different species varies, with the nudibranchs displaying the highest levels in our study, and starfish the highest concentrations in the Cape Hatt, Baffin Island study (Cretney *et al.* 1987c). However, the levels reported for our samples are within the range reported for uncontaminated invertebrates by Clarke and MacLeod (1977).

In the sculpin samples collected during the Polar Star cruise, the tPAHs were very low compared to other fish collected in the Beaufort Sea (Table 24), or in other areas of the Arctic, such as Canada (Lockhart *et al.*, 1992) and Finland (about 260 ng/g d.w., Rainio *et al.*, 1986). As for the invertebrates, the concentrations found in fish are similar to those found in uncontaminated areas.

Table 24: PAHs Concentrations in Arctic Biota (ng/g d.w.)

Invertebrates	TPAHs	Vertebrates	TPAHs
Polar Star Av.	24-161	**Polar Star Av.°**	19.9
Beaufort Sea*	ND-2400	**1**	240
Baffin Is.**	10-110	**2**	630
Baffin Is.***	380-4080	**3**	148
		4	87-263

* *Anonyx, Astarte, Cyrtodaria, Macoma*, and *Portlandia*, Boehm *et al.*, 1990; ***Astarte*, *** Starfish, Cretney *et al.*, 1987; °Sculpin; 1 : Herring, Enviro Test, 1984; 2: Flounder, 3: Arctic cod, Muir *et al.*, 1987; 4: Least cisco, Wong *et al.*, 1976.

*Organochlorine Compounds

Very few data exist for organochlorine compounds in marine invertebrates from Arctic areas, and it is difficult to compare the results between different studies because the same species were generally not analyzed. For example, we analyzed benthic fauna including mollusks, crustaceans, and echinoderms while the little data that we could find for the rest of the Arctic are mostly for plankton species (e.g., zooplankton, Bidleman *et al.*, 1989). However, Polar Star data can be compared with the other NS&T data because the analyses are also for benthic invertebrates. In the invertebrates collected during the Polar Star cruise, average concentrations of dieldrin and total chlordanes were slightly higher than the average concentrations in the other Alaskan NS&T samples. Average concentrations of tDDT and tPCBs were

lower than the average in the other NS&T samples from Alaska and the entire U.S. (Table 25).

For the fish samples collected during the Polar Star cruise, the same difficulty arises because the data that are available for other areas are not for the same species. It appears, however, that the average concentrations of all the organochlorine compounds analyzed for this study are either similar to or lower than the average concentrations in fish collected by the NS&T program in Alaska, around the U.S., or in most fish collected elsewhere in the Arctic (Muir *et al.*, 1987; 1988; Anderson, 1988; Thomas, 1988; Thomas and Hamilton, 1988; Paarsivirta and Rantio, 1991; Lockhart *et al.*, 1992; Muir *et al.*, 1992).

Table 25: Organochlorine Compound Concentrations* in Arctic Biota
(ng/g d.w.)

	tPCBs	tChlor	tDDT
Invertebrates			
Polar Star Av.	≈29.6†	2.51	1.67
Ice Island*	130	100	60
Vertebrates			
Polar Star Av.	≈20.4†	7.95	3.22
Frobisher Bay**	28	10	32
N. Finland***	5700	1280	1470
Labrador Sea°	350	40	100
N.Baffin Is. °°	90	80	90
W. Davis Strait°°°	450	260	90

*Zooplankton, Bidleman *et al.*, 1989; **Greenland cod, Muir *et al.*, 1987; ***Atlantic cod, Paarsivirta and Rantio, 1991; °Atlantic salmon, Andersson *et al.*, 1988; °°Arctic char, Thomas and Hamilton, 1988; °°°Arctic char, Muir *et al.*, 1986; †tPCBs is about equal to twice the tPCB congeners, for bivalves Texas A&M calculated ΣPCBs = 2.2(Σcongeners)+2.8).

The maximum concentrations recommended in fish for human consumption (tolerable daily intake-TDI, or acceptable daily intake-ADI) range from 1000 to 3000 ng/g per day for tPCBs and from 5000 to 20000 ng/g per day for tDDTs (Ontario Guide of Eating Sport Fish; 1988; FDA, 1987; WHO, 1993; Richardson, 1996; Jensen *et al.*, 1997). Compared to these values, the concentrations in the Polar Star samples are extremely low and should not present any danger.

Conclusion

From the data obtained in this study, it appears that sediments and biota from the western Beaufort Sea sampled during the Polar Star cruise in 1993 were not heavily contaminated compared to the rest of Alaska, the United States and the Arctic.

The contamination by radionuclides is very likely due to global fallout resulting from bomb testing several decades ago. The only anomaly found was for ^{137}Cs which was elevated in certain samples taken during the Polar Star cruise. This may be due to input of ^{137}Cs to the environment resulting either from the Chernobyl accident or from local sources. A more comprehensive and detailed study needs to be performed in order to test these hypothesis.

Arsenic was, on average, more concentrated in the sediments analyzed for this study than in most other places in the Arctic for which we have data, but no anthropogenic sources have been identified and the high concentrations may be related to natural background.

Finally, several organic contaminants were usually detected in both sediments and biota but were generally found at very low concentrations, lower than in any of the other areas with which our data were compared. Even PAHs which are known to be at high concentrations in some areas of the Beaufort Sea, were not highly concentrated in our samples.

In conclusion, the area studied during the Polar Star cruise appears to have been very little impacted by anthropogenic pollution. However, the data are few and such studies should be extended to other areas of the Beaufort Sea in order to get a good baseline of contamination levels in the U.S. Arctic. This baseline is indispensable to assess, in future years, the potential export of contamination from areas of the Former Soviet Union to the American Arctic.

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APPENDICES

Appendix A
Tables

A1-Radionuclides in Sediments from the Beaufort Sea - Activities in Bq/kg

Station	G. Size	Clay %	TOC %	TIC%	137Cs	Std	40K	Std	212Pb	Std	214Pb **	Std	137Cs **	Std	137CsC **	90Sr	Std	238Pu	Pu°	Std	241Am	Std
B1	0.64	11.40	0.59	0.90	<3		452	27	22.30	2.90	19.80	2.80	2.70	0.30	4.23	<0.7		<0.02	0.14	0.02	0.07	0.01
B4	0.98	48.00	1.79	2.07	5.30	1.80	567	28	44.70	3.60	22.60	2.70	4.50	0.40	4.57	0.24	0.12	<0.02	0.34	0.03	0.11	0.01
C1	0.99	51.30	1.17	1.32	<2		671	16	41.00	2.50	16.70	2.00	3.20	0.30	3.24	<0.7		<0.02	0.05	0.02	<0.1	
C3	0.99	39.30	0.97	1.24	<4		699	42	57.00	4.00	93.30	5.60	4.50	0.40	4.52	<0.7		<0.01	0.06	0.01	<0.1	
D1	0.97	24.40	0.55	1.36	3.10	1.10	524	21	44.10	2.20	59.50	3.60	2.30	0.20	2.38	<0.5		<0.03	<0.2		0.06	0.01
E1	1.00	56.00	0.72	1.01	<3		888	36	62.00	3.10	62.30	4.40	0.90	0.10	0.90	<0.6		<0.02	<0.03		<0.1	
E5	0.99	47.00	1.01	1.25	8.20	2.10	698	35	41.30	3.70	39.30	3.90	9.70	0.70	9.82	0.60	0.30	<0.09	<0.14		<0.3	
E7	0.92	41.50	1.47	1.78	11.40	2.30	585	41	43.90	3.90	13.70	3.40	12.40	0.90	13.42	<1.2		<0.03	0.52	0.50		
E12	0.90	39.20	1.18	1.43	5.50	1.60	582	29	33.60	3.00	26.00	1.80	3.10	0.20	3.45	<0.6		<0.01	0.09	0.01	0.09	0.02
E12	0.90	39.20	1.18	1.43	6.10	2.30	590	41	33.80	3.70	24.20	3.60	4.40	0.30	4.89	<0.6		<0.06	0.27	0.02	0.10	0.01
E12	0.90	39.20	1.18	1.43	<4		593	36	28.60	3.40	20.70	3.30	3.10	0.50	3.45	<1.2		<0.01	0.14	0.01	0.07	0.01
G11	0.74	28.60	1.33	1.67	7.70	1.50	500	30	43.00	2.60	21.50	2.60	8.20	1.10	11.04	<1.2		<0.01	0.27	0.02	<0.3	
Mean		38.76	1.09	1.41	6.76		612		41.28		34.97		4.92		5.49	0.42		-	0.21		0.08	
Std		12.34	0.36	0.32	2.65		115		11.05		24.35		3.41		3.82	0.25			0.16		0.02	
Median		39	1.18	1.39	6.10		588		42		23.4		3.8		4.4	0.4			0.14		0.08	

Station	Cs/Sr	240/239*	Cs/Pu°	Pu°/Cs	Am/Pu°
B1		0.17	19.29	0.052	0.500
B4	18.8	0.18	13.24	0.076	0.324
C1		0.20	64.00	0.016	
C3		0.19	75.00	0.013	
D1		0.19			
E1		0.18			
E5	16.2	0.19			
E7		0.18	23.85	0.042	
E12		0.24	34.44	0.029	1.000
E12		0.20	16.30	0.061	0.370
E12		0.17	22.14	0.045	0.500
G11		0.18	30.37	0.033	
Mean	**17.5**	**0.19**	**33.18**	**0.04**	**0.54**
Std	**1.8**	**0.02**	**21.77**	**0.02**	**0.27**
Median	**17.5**	**0.19**	**23.85**	**0.042**	**0.500**

Legend

* 240Pu/239Pu ratio

**Measurement after chemical separation

137Cs**C=137Cs Activities obtained after chemical separation and corrected for sediment grain size

Pu°=239+240Pu

Std=Standard deviation

Marine Invertebrates										**		**							
Station	Sample Type	137Cs	Std	40K	Std	212Pb	Std	214Pb	Std	137Cs	Std	90Sr	Std	238Pu	Std	*Pu	Std	241Am	Std
B-4	Sipunculids	< 1.0		309	6	10.4	0.9	5.9	0.8	1.1	0.2	< 1.0		< 0.01		< 0.03		< 0.08	
E-7	Crinoids	< 0.8		201	4	<0.6		<0.9		0.7	0.2	< 0.9		< 0.01		0.08	0.02	< 0.06	
G-1	Sea urchins	< 2.2		182	20	5.6	2.1	<2.4		0.6	0.1	< 0.6		< 0.02		< 0.02		< 0.02	
G-1	Spider crab	< 0.8		209	25	2.5	1.8	4.51	0.7	0.5	0.1	< 0.3		< 0.01		0.02	0.01	< 0.02	
G-1	Reg. starfish°	< 1.2		265	8	9.9	1.2	6.6	1.1	0.8	0.1	< 0.5		< 0.06		< 0.08		< 0.02	
G-1	Soft starfish	< 0.8		243	5	3.9	0.7	3.2	0.6			< 0.9		< 0.01		< 0.01		< 0.05	
G-1	Nudibranchs	< 2.0		272	19	<2.5		4.3	1.1	0.3	0.1	< 0.4		< 0.01		< 0.01		< 0.02	
		Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
		-	-	240	45	6.5	3.5	4.9	1.4	0.7	0.3	-	-	-	-	0.05	0.04	-	-
	Median			243		5.60		4.51		0.65						0.05			
Marine Vertebrates																			
1	Bh wh blub	< 0.08		15	2	0.3	0.1	< 0.08		< 0.00005		< 0.008		< 0.004		< 0.003		< 0.0006	
2	Bh wh lung	< 0.07		189	10	< 0.08		< 0.07		0.02	0.02	0.05	0.01	< 0.001		< 0.002		< 0.002	
3	Bh wh liver	0.44	0.12	223	5	0.5	0.2	0.5	0.3	0.44	0.04	0.05	0.01	< 0.0001		< 0.001		< 0.004	
4	Kg eider bone	< 0.5		35	5	< 0.5		< 0.5		< 0.5		0.02	0.01	< 0.02		< 0.03			
5	Kg eider mus	< 0.4		305	6	< 0.5		< 0.4		0.3	0.03	0.05	0.02	< 0.0007		< 0.001		< 0.002	
6	Bded seal blub	< 0.2		10		< 0.3		< 0.3		< 0.2		< 0.02		< 0.004		< 0.005		< 0.004	
7	Bded seal kidn	< 0.2		352	51	0.8	0.1	< 0.4		< 0.2		< 0.003		< 0.004		< 0.008		< 0.01	
		Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
		0.44	-	161	142	0.53	0.25	0.50	-	0.25	0.21	0.04	0.02	-	-	-	-	-	-
	Median	0.44		189		0.50		0.50		0.30		0.05							
All biota combined																			
		Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
		0.44	-	201	56	3.5	4.2	2.7	3.1	0.5	0.3	0.04	-	-	-	0.05	-	-	-

Legend

°	Star fish
1	Bowhead whale blubber
2	Bowhead whale lung
3	Bowhead whale liver
4	King eider bone
5	King eider muscle
6	Bearded seal blubber
7	Bearded seal kidney

*Pu= 239+240Pu

** Measurement after chemical separation

Std =Standard deviation

A3-Trace Metal Concentrations in Sediments from the Beaufort Sea - Concentrations in ppm

Site	Grain Size	Ag	Ag Cor	Al	Al Cor	As	As Cor	Cd	Cd Cor	Cr	Cr Cor	Cu	Cu Cor	Fe	Fe Cor	Hg	Hg Cor	Mn	Mn Cor
B-01	0.64	0.050	0.078	58000	90767	10	16	0.06	0.10	79	124	11	17	26000	40689	0.041	0.064	330	516
B-04	0.98	0.080	0.081	47000	47764	29	30	0.16	0.16	87	88	24	24	45000	45732	0.050	0.051	360	366
C-01	0.99	0.072	0.073	65000	65723	14	14	0.43	0.43	79	80	37	37	45000	45501	0.153	0.155	1200	1213
C-03	0.99	0.031	0.031	66000	66332	35	35	0.08	0.08	79	79	39	40	51000	51257	0.085	0.085	13000	13065
D-01	0.97			72000	74380	36	37	0.14	0.14	82	85	61	63	52000	53719	0.077	0.080	7900	8161
E-01	1.00			80000	80080	42	42	0.10	0.10	103	103	63	63	49500	49550	0.082	0.082	5250	5255
E-05	0.99	0.031	0.031	73000	73887	29	30	0.09	0.09	81	82	38	39	49000	49595	0.083	0.084	5800	5870
E-07	0.92	0.076	0.082	53000	57359	38	41	0.15	0.16	77	83	28	30	45000	48701	0.070	0.076	7000	7576
E-12	0.90	0.058	0.065	55000	61179	17	19	0.10	0.11	110	122	20	22	36000	40044	0.057	0.063	300	334
G-11	0.74	0.132	0.178	53000	71357	43	58	0.17	0.23	91	123	25	34	39000	52508	0.065	0.088	620	835
Mean		0.07	0.09	62800	68773	34	38	0.12	0.14	92	103	35	37	43700	48080	0.071	0.079	3794	3974
Std		0.04	0.06	12775	9336	11	15	0.04	0.06	14	20	17	15	6017	4717	0.011	0.009	3111	3214
Median		0.07	0.07	55000	71357	37.70	40.80	0.10	0.11	91.00	103.10	27.50	33.66	45000	49550	0.07	0.08	5250	5255
Max		0.13	0.18	80000	80080	42.80	57.62	0.17	0.23	110.00	122.52	62.90	62.96	49500	52508	0.08	0.09	7000	7576
Min		0.03	0.03	53000	57359	16.70	18.58	0.09	0.09	77.00	81.98	19.90	22.14	36000	40044	0.06	0.06	300	334

Site	Grain Size	Ni	Ni Cor	Pb	Pb Cor	Sb	Sb Cor	Se	Se Cor	Si	Si Cor	Sn	Sn Cor	Zn	Zn Cor
B-01	0.64	21	32	11	17	0.79	1.24	0.63	0.99	330000	516432	1.60	2.50	65	102
B-04	0.98	32	33	15	15	1.00	1.02	0.62	0.63	260000	264228	2.00	2.03	120	122
C-01	0.99	40	40	20	20	2.50	2.53	0.62	0.63	270000	273003	2.30	2.33	150	152
C-03	0.99	55	56	23	23	3.10	3.12	0.39	0.39	250000	251258	2.50	2.51	160	161
D-01	0.97	75	77	23	24	1.40	1.45	0.08	0.08	230000	237603	2.70	2.79	140	145
E-01	1.00	73	73	25	25	1.50	1.50	0.12	0.12	240000	240240	3.25	3.25	140	140
E-05	0.99	50	50	23	23	1.30	1.32	0.23	0.23	260000	263159	2.70	2.73	130	132
E-07	0.92	45	49	21	23	1.40	1.52	0.47	0.51	260000	281385	2.20	2.38	120	130
E-12	0.90	32	36	17	19	0.87	0.97	0.31	0.34	290000	322581	2.00	2.22	98	109
G-11	0.74	33	44	12	15	1.80	2.42	0.15	0.20	280000	376981	1.80	2.42	92	123
Mean		47	50	20	21	1.37	1.54	0.26	0.28	266000	296869	2.39	2.60	116	127
Std		16	14	5	4	0.34	0.54	0.14	0.15	19494	53995	0.59	0.41	21	12
Median		45	49	21	23	1.40	1.50	0.23	0.23	260000	281385	2.20	2.42	120	130
Max		73	73	25	25	1.80	2.42	0.47	0.51	290000	376981	3.25	3.25	140	140
Min		32	36	12	15	0.87	0.97	0.12	0.12	240000	240240	1.80	2.22	92	109

Station	B-01	B-04	C-01	C-03	D-01	E-01	E-05	E-07	E-12	G-11
	NCor	NCor	NCor	NCor	NCor	NCor	NCor	NCor	NCor	NCor
Compound										
NAPHTHALENE	5.95	11.32	14.05	13.91	12.05	29.59	14.75	13.65	7.08	20.35
C1-NAPHTHALENES	13.40	25.18	35.11	34.24	28.12	66.98	34.34	32.28	14.57	52.86
C2-NAPHTHALENES	18.46	39.25	56.35	51.93	36.57	92.90	50.40	46.35	22.81	82.23
C3-NAPHTHALENES	15.70	36.62	47.85	34.44		85.15	44.96	46.25	21.46	76.06
C4-NAPHTHALENES						44.68				43.72
2-METHYLNAPHTHALENE	13.86	26.52	36.91	35.81	28.24	69.91	36.72	32.63	15.08	56.29
1-METHYLNAPHTHALENE	10.83	20.66	30.33	27.50	0.00	59.79	29.05	26.23	12.38	44.68
2,6-DIMETHYLNAPHTHALENE	10.04	23.97	30.23	27.06	19.58	44.19	25.56	24.81	11.74	42.47
1,6,7-TRIMETHYLNAPHTHALENE	5.94	12.07	17.76	14.01	10.38	28.62	12.08	15.22	6.81	25.49
Total naphthalenes	**53.5**	**112.4**	**153.4**	**134.5**	**76.7**	**319.3**	**144.5**	**138.5**	**65.9**	**275.2**
% of total PAHs	**33.6**	**27.2**	**24.6**	**24.7**	**27.0**	**29.2**	**33.0**	**54.2**	**29.9**	**32.4**
BIPHENYL	3.97	8.63	11.58	10.61	9.21	13.24	9.21	10.05	4.82	13.34
ACENAPHTHYLENE										
ACENAPHTHENE										
DIBENZOFURAN	3.39	7.61	6.82	5.71	4.63	10.57	5.58	1.07	3.49	10.87
FLUORENE						6.32				7.13
C1-FLUORENES										
C2-FLUORENES										
C3-FLUORENES										
Total Fluorenes						**6.3**				**7.1**
% of total PAHs						**0.6**				**0.8**
PHENANTHRENE	11.26	25.63	41.70	42.57	31.34	64.98	32.31	10.06	13.69	40.20
1-METHYLPHENANTHRENE	4.15	8.34	11.82	13.19	6.89	22.69	10.87	9.68	5.05	15.64
ANTHRACENE								11.01		
C1-PHENANTHRENE/ANTHRACENES	17.97	44.90	69.71	62.80	38.20	104.52	49.10		23.06	69.85
C2-PHENANTHRENE/ANTHRACENES	16.49	39.59	58.23	53.45	29.78	95.75	41.56		21.03	64.38
C3-PHENANTHRENE/ANTHRACENES		25.33	31.17	35.20	17.49	60.07	26.80		12.96	39.28
C4-PHENANTHRENE/ANTHRACENES			32.90			44.12				31.69
Total phenanthrene/anthracenes	**45.7**	**135.4**	**233.7**	**194.0**	**116.8**	**369.4**	**149.8**	**21.1**	**70.7**	**245.4**
% of total PAHs	**28.7**	**32.8**	**37.5**	**35.6**	**41.1**	**33.8**	**34.2**	**8.2**	**32.1**	**28.9**
DIBENZOTHIOPHENE		4.12	4.55	5.80	4.22	10.25	2.71		0.99	6.51
C1-DIBENZOTHIOPHENES		9.85	13.52	13.30	8.62	22.02	9.93		5.02	18.25
C2-DIBENZOTHIOPHENES		10.59	15.17	14.91	1.40	23.26	11.56			17.18
C3-DIBENZOTHIOPHENES			13.70			20.42	8.47			15.44
Total dibenzothiophenes		**24.6**	**46.9**	**34.0**	**14.2**	**76.0**	**32.7**		**6.0**	**57.4**
% of total PAHs		**5.9**	**7.5**	**6.2**	**5.0**	**7.0**	**7.5**		**2.7**	**6.8**
FLUORANTHENE	2.18	4.38	5.90	6.58	2.27	8.55	3.75	6.68	1.85	8.89
PYRENE	2.44	5.60	10.28	9.52	2.90	13.81	5.44	7.13	2.81	10.02
C1-FLUORANTHENES/PYRENES	8.29	18.47	26.66	24.02	1.87	41.00	16.51		11.00	36.29
BENZ(A)ANTHRACENE	1.45	2.06	3.18	3.68	1.53	4.45	2.25	3.19	1.34	3.98
CHRYSENE	4.34	10.39	18.94	19.83	12.29	28.27	12.82	5.18	5.94	17.56
C1-CHRYSENES	4.04	12.51	19.97	20.61	9.49	29.99	10.22		5.74	16.09
C2-CHRYSENES	6.96	17.76	23.18	28.70	12.70	41.91	14.79		9.12	23.16
C3-CHRYSENES						27.59				24.24
C4-CHRYSENES										
Total chrysenes	**15.3**	**40.7**	**62.1**	**69.1**	**34.5**	**127.8**	**37.8**	**5.2**	**20.8**	**81.1**
% of total PAHs	**9.6**	**9.8**	**10.0**	**12.7**	**12.1**	**11.7**	**8.6**	**2.0**	**9.4**	**9.5**
BENZO(B)FLUORANTHENE	3.27	6.93	12.53	13.41	6.47	22.51	7.34	9.38	3.96	13.09
BENZO(K)FLUORANTHENE	0.29	0.71		1.38		2.41	0.87	0.39	0.39	1.66
BENZO(E)PYRENE	2.76	6.64	11.87	12.83	6.12	27.26	7.12	9.17	4.00	12.10
BENZO(A)PYRENE	0.85	1.45	2.00	2.12		3.18	1.35	8.72	0.74	2.63
PERYLENE	**12.31**	**29.08**	**24.26**	**9.98**	**1.90**	**22.55**	**7.42**	**24.41**	**17.57**	**55.91**
% of total PAHs	**7.7**	**7.0**	**3.9**	**1.8**	**0.7**	**2.1**	**1.7**	**9.6**	**8.0**	**6.6**
INDENO(1,2,3-C,D)PYRENE	0.70	1.56	2.14	2.36	0.81	4.10	1.27	1.99	0.84	3.05
DIBENZ(A,H)ANTHRACENE	0.57	1.12	1.57	1.70	0.75	2.78	0.70	0.90	0.75	1.59
BENZO(G,H,I)PERYLENE	2.43	6.10	8.73	8.88	3.20	17.00	4.35	7.57	3.60	9.99
Total PAHs	**159**	**413**	**624**	**544**	**284**	**1092**	**438**	**255**	**221**	**850**
Grain Size Coefficient	0.64	0.98	0.99	0.99	0.97	1.00	0.99	0.92	0.90	0.74

Legend

NCor= Raw concentrations — tAv NCor = Average of uncorrected values — Std NCor = Standard deviation of uncorrected values

Cor = Concentrations corrected for grain size — tAv. Cor = Average of corrected values — Std Cor = Standard deviation of corrected values

Station	B-04	C-01	C-03	D-01	E-01	E-05	E-07	E-12	G-11	tAv.	Std	tAv.	Std
	Cor	Cor	Cor	Cor	Cor	Cor	Cor	Cor	Cor	NCor	NCor	Cor	Cor
Compound													
NAPHTHALENE	11.50	14.21	13.98	12.45	29.59	14.93	14.78	7.88	27.40	*14.3*	*6.7*	*16.5*	*7.2*
C1-NAPHTHALENES	25.59	35.50	34.41	29.05	66.98	34.76	34.93	16.20	71.16	*33.7*	*16.2*	*39.3*	*18.2*
C2-NAPHTHALENES	39.89	56.98	52.19	37.78	92.90	51.02	50.16	25.37	110.71	*49.7*	*23.5*	*57.8*	*27.2*
C3-NAPHTHALENES	37.22	48.38	34.61	0.00	85.15	45.51	50.06	23.87	102.41	*45.4*	*22.9*	*47.5*	*29.8*
C4-NAPHTHALENES					44.68				58.86	*44.2*	*0.7*	*51.8*	*10.0*
2-METHYLNAPHTHALENE	26.95	37.32	35.99	29.17	69.91	37.17	35.31	16.77	75.79	*35.2*	*17.1*	*41.0*	*19.4*
1-METHYLNAPHTHALENE	21.00	30.67	27.64	0.00	59.79	29.40	28.39	13.77	60.16	*26.1*	*17.1*	*30.4*	*18.9*
2,6-DIMETHYLNAPHTHALENE	24.36	30.57	27.20	20.23	44.19	25.87	26.85	13.06	57.18	*26.0*	*11.2*	*30.2*	*13.2*
1,6,7-TRIMETHYLNAPHTHALENE	12.27	17.95	14.08	10.72	28.62	12.23	16.47	7.58	34.31	*14.8*	*7.4*	*17.3*	*8.6*
Total naphthalenes	**114.2**	**155.1**	**135.2**	**79.3**	**319.3**	**146.2**	**149.9**	**73.3**	**370.5**	***147.4***	***86.8***	***172.6***	***101.4***
% of total PAHs	**27.6**	**24.9**	**24.8**	**27.9**	**29.2**	**33.4**	**58.7**	**33.2**	**43.6**	***31.6***	***8.6***	***35.9***	***12.0***
BIPHENYL	8.77	11.71	10.66	9.51	13.24	9.32	10.88	5.36	17.96	*9.5*	*3.1*	*10.9*	*3.6*
ACENAPHTHYLENE													
ACENAPHTHENE													
DIBENZOFURAN	7.73	6.89	5.74	4.78	10.57	5.64	1.16	3.88	14.63	*6.0*	*3.1*	*6.9*	*3.7*
FLUORENE					6.32				9.60	*6.7*	*0.6*	*8.0*	*2.3*
C1-FLUORENES													
C2-FLUORENES													
C3-FLUORENES													
Total Fluorenes					**6.3**				**9.6**	***6.7***	***0.6***	***8.0***	***2.3***
% of total PAHs					**0.6**				**1.1**	***0.7***	***0.2***	***0.9***	***0.4***
PHENANTHRENE	26.05	42.16	42.78	32.38	64.98	32.71	10.88	15.22	54.12	*31.4*	*17.1*	*36.0*	*17.4*
1-METHYLPHENANTHRENE	8.48	11.95	13.26	7.12	22.69	11.00	10.48	5.62	21.06	*10.8*	*5.5*	*12.5*	*5.9*
ANTHRACENE	0.00						11.91		0.00	*11.0*		*4.0*	*6.9*
C1-PHENANTHRENE/ANTHRACENES	45.63	70.48	63.12	39.46	104.52	49.69		25.65	94.05	*53.3*	*26.8*	*61.9*	*27.7*
C2-PHENANTHRENE/ANTHRACENES	40.24	58.88	53.72	30.76	95.75	42.06		23.40	86.67	*46.7*	*24.6*	*54.2*	*25.9*
C3-PHENANTHRENE/ANTHRACENES	25.74	31.52	35.38	18.07	60.07	27.13		14.41	52.88	*31.0*	*14.6*	*35.8*	*16.0*
C4-PHENANTHRENE/ANTHRACENES	0.00	33.27			44.12				42.67	*36.2*	*6.9*	*30.0*	*20.6*
Total phenanthrene/anthracenes	**137.7**	**236.3**	**195.0**	**120.7**	**369.4**	**151.6**	**22.8**	**78.7**	**330.4**	***158.2***	***105.7***	***181.7***	***112.6***
% of total PAHs	**33.3**	**37.9**	**35.8**	**42.5**	**33.8**	**34.6**	**8.9**	**35.7**	**38.9**	***31.3***	***8.9***	***34.5***	***9.8***
DIBENZOTHIOPHENE	4.18	4.60	5.83	4.36	10.25	2.75		1.10	8.76	*4.9*	*2.8*	*5.8*	*3.0*
C1-DIBENZOTHIOPHENES	10.01	13.67	13.37	8.90	22.02	10.05		5.59	24.57	*12.6*	*5.5*	*14.7*	*6.6*
C2-DIBENZOTHIOPHENES	10.76	15.34	14.99	1.45	23.26	11.70			23.13	*13.4*	*6.7*	*14.4*	*7.6*
C3-DIBENZOTHIOPHENES		13.85			20.42	8.57			20.79	*14.5*	*4.9*	*15.9*	*5.8*
Total dibenzothiophenes	**25.0**	**47.5**	**34.2**	**14.7**	**76.0**	**33.1**		**6.7**	**77.2**	***36.5***	***23.0***	***43.9***	***26.2***
% of total PAHs	**6.0**	**7.6**	**6.3**	**5.2**	**7.0**	**7.6**		**3.0**	**9.1**	***6.1***	***1.6***	***7.0***	***1.8***
FLUORANTHENE	4.45	5.96	6.61	2.35	8.55	3.80	7.23	2.06	11.98	*5.1*	*2.6*	*6.0*	*3.1*
PYRENE	5.69	10.40	9.57	3.00	13.81	5.50	7.72	3.12	13.49	*7.0*	*3.8*	*8.1*	*4.1*
C1-FLUORANTHENES/PYRENES	18.77	26.96	24.14	1.93	41.00	16.71		12.23	48.86	*20.5*	*12.9*	*23.9*	*14.7*
BENZ(A)ANTHRACENE	2.09	3.22	3.70	1.58	4.45	2.28	3.45	1.49	5.36	*2.7*	*1.1*	*3.2*	*1.3*
CHRYSENE	10.56	19.15	19.93	12.70	28.27	12.98	5.61	6.61	23.64	*13.6*	*7.6*	*15.5*	*7.8*
C1-CHRYSENES	12.72	20.19	20.71	9.80	29.99	10.35		6.39	21.67	*14.3*	*8.2*	*16.5*	*8.1*
C2-CHRYSENES	18.05	23.43	28.84	13.12	41.91	14.97		10.14	31.19	*19.8*	*10.9*	*22.8*	*10.8*
C3-CHRYSENES					27.59				32.64	*25.9*	*2.4*	*30.1*	*3.6*
C4-CHRYSENES													
Total chrysenes	**41.3**	**62.8**	**69.5**	**35.6**	**127.8**	**38.3**	**5.6**	**23.1**	**109.1**	***49.4***	***36.6***	***57.1***	***39.1***
% of total PAHs	**10.0**	**10.1**	**12.8**	**12.5**	**11.7**	**8.7**	**2.2**	**10.5**	**12.8**	***9.6***	***3.0***	***10.7***	***3.5***
BENZO(B)FLUORANTHENE	7.04	12.67	13.48	6.68	22.51	7.43	10.15	4.41	17.63	*9.9*	*5.7*	*11.4*	*5.9*
BENZO(K)FLUORANTHENE	0.72		1.39		2.41	0.88	0.42	0.43	2.24	*1.0*	*0.7*	*1.2*	*0.8*
BENZO(E)PYRENE	6.75	12.01	12.89	6.32	27.26	7.21	9.92	4.44	16.29	*10.0*	*7.0*	*11.4*	*7.0*
BENZO(A)PYRENE	1.47	2.03	2.13		3.18	1.36	9.44	0.82	3.54	*2.6*	*2.4*	*3.1*	*2.6*
PERYLENE	**29.55**	**24.53**	**10.03**	**1.96**	**22.55**	**7.51**	**26.42**	**19.55**	**75.28**	***20.5***	***15.1***	***24.1***	***20.2***
% of total PAHs										***4.2***		***4.3***	
INDENO(1,2,3-C,D)PYRENE	1.58	2.16	2.37	0.84	4.10	1.29	2.15	0.93	4.11	*1.9*	*1.1*	*2.2*	*1.2*
DIBENZ(A,H)ANTHRACENE	1.14	1.59	1.71	0.77	2.78	0.71	0.98	0.83	2.14	*1.2*	*0.7*	*1.4*	*0.7*
BENZO(G,H,I)PERYLENE	6.20	8.83	8.92	3.31	17.00	4.40	8.20	4.00	13.45	*7.2*	*4.4*	*8.2*	*4.5*
Total PAHs	**422**	**630**	**550**	**293**	**1092**	**442**	**278**	**245**	**1148**	***488***	***298***	***567***	***338***
Grain Size Coefficient													
Legend													
NCor= Raw concentrations		tAv NCor = Average of uncorrected values					Std NCor = Standard deviation of uncorrected values						
Cor = Concentrations corrected for grain size		tAv. Cor = Average of corrected values					Std Cor = Standard deviation of corrected values						

Compound	Station B-04 Small Clams	Station B-04 Macoma calcarea	Station G-01 Gastropods	Station G-01 Sea Urchins	Station G-01 Nudibranches	Station G-01 Clams	Station G-01 Hermit Crabs	Station G-01 Small Shrimps	Station G-01 Carid Shrimps	*tAver.*	*Std*	Station G-01 Sculpin
NAPHTHALENE	7.84	17.16	17.14	6.18	9.60	18.78	16.28	18.04	16.34	*14.15*	*4.8*	11.63
2-METHYLNAPHTHALENE	5.84	13.46	13.25	3.91	9.24		11.16	7.93	16.04	*10.10*	*4.1*	8.30
1-METHYLNAPHTHALENE	4.80	10.54	7.83	3.39	8.81		8.41	5.98	14.38	*8.02*	*3.5*	7.45
C1-NAPHTHALENES	5.81	11.95	10.42	4.54	9.38		10.01	7.86	16.61	*9.57*	*3.8*	8.28
2,6-DIMETHYLNAPHTHALENE		11.09			10.51					*10.80*	*0.4*	
C2-NAPHTHALENES		28.23								*28.23*		
1,6,7-TRIMETHYLNAPHTHALENE												
C3-NAPHTHALENES												
C4-NAPHTHALENES												
Total Naphthalenes	**13.66**	**57.34**	**27.56**	**10.72**	**18.98**	**18.78**	**26.29**	**25.90**	**32.95**	*25.80*	*13.8*	**19.91**
% of total PAHs	**35.66**	**37.79**	**71.25**	**30.78**	**11.76**	**76.82**	**50.20**	**77.05**	**46.73**	*38.32*		**100**
BIPHENYL	8.80	26.94	6.38	11.02	9.26		12.76	6.20		*11.62*	*7.1*	
ACENAPHTHYLENE												
ACENAPHTHENE												
DIBENZOFURAN	2.86	4.06		6.25	3.78					*4.24*	*1.4*	
FLUORENE				6.84						*6.84*		
C1-FLUORENES												
C2-FLUORENES												
C3-FLUORENES												
Total Fluorenes				**6.84**						*6.84*		
% of total PAHs				**19.63**						*10.15*		
PHENANTHRENE	3.34	6.80	2.14		7.76				7.33	*5.47*	*2.6*	
1-METHYLPHENANTHRENE		4.72			3.30					*4.01*	*1.0*	
ANTHRACENE		2.57								*2.57*		
C1-PHENAN/ANTHRA		15.60			12.40					*14.00*	*2.3*	
C2-PHENAN/ANTHRA												
C3-PHENAN/ANTHRA												
C4-PHENAN/ANTHRA												
Total Phenan/Anthra	**3.34**	**24.96**	**2.14**		**20.16**				**7.33**	*11.59*	*10.3*	
% total PAHs	**8.72**	**16.45**	**5.53**		**12.49**				**10.39**	*17.21*		
DIBENZOTHIOPHENE												
C1-DIBENZOTHIOPHENES												
C2-DIBENZOTHIOPHENES												
C3-DIBENZOTHIOPHENES												
Total Dibenzothiophenes												
%total PAHs												
FLUORANTHENE	1.80	3.44	1.40		5.36				4.83	*3.36*	*1.8*	
PYRENE	1.49	3.33	1.20		3.10				4.13	*2.65*	*1.3*	
C1-FLUORANTHENES/PYRENES					10.95					*10.95*		
BENZ(A)ANTHRACENE		1.57			1.34					*1.46*	*0.2*	
CHRYSENE	1.10	3.47			5.37					*3.32*	*2.1*	
C1-CHRYSENES		4.96			10.46					*7.71*	*3.9*	
C2-CHRYSENES					25.51					*25.51*		
C3-CHRYSENES												
C4-CHRYSENES												
Total Chrysenes	**1.10**	**8.43**			**41.34**					*16.96*	*21.4*	
% total PAHs	**2.88**	**5.56**			**25.62**					*25.19*		
BENZO(B)FLUORANTHENE		2.48			4.78				4.04	*3.77*	*1.2*	
BENZO(K)FLUORANTHENE		0.31			0.81					*0.56*	*0.4*	
BENZO(E)PYRENE	0.90	2.23			5.99				3.11	*3.06*	*2.2*	
BENZO(A)PYRENE		0.51			1.03					*0.77*	*0.4*	
Perylene	**4.35**	**11.49**			**28.84**	**5.67**	**13.32**	**1.52**	**11.51**	*10.96*	*9.0*	
% total PAHs	**11.4**	**7.6**			**17.9**	**23.2**	**25.4**	**4.5**	**16.3**	*16.3*		
INDENO(1,2,3-C,D)PYRENE												
DIBENZ(A,H)ANTHRACENE												
BENZO(G,H,I)PERYLENE		4.63			5.65				2.62	*4.30*	*1.5*	
Total PAHs	**38.29**	**151.73**	**38.68**	**34.83**	**161.37**	**24.45**	**52.37**	**33.62**	**70.52**	*67.32*	*52.3*	**19.91**

Legend

tAver. = Average of all invertebrate specimen

Std = Standard deviation of the concentrations

C1-PHENAN/ANTHRA = C1-Phenanthrene/Anthracene

C2-PHENAN/ANTHRA = C2-Phenanthrene/Anthracene

C3-PHENAN/ANTHRA = C3-Phenanthrene/Anthracene

C4-PHENAN/ANTHRA = C41-Phenanthrene/Anthracene

Total Phenan/Anthra = Total Phenanthrene/Anthracene

Compound	B-04	G-01	G-01	G-01	B-04	G-01	G-01	G-01	G-01	*Aver. Inv.*	*Std*	G-01
	Small Clams	Gastropods	Sea Urchins	Nudibranches	Macoma Calcarea	Clams	Hermit Crabs	Small Shrimps	Carid Shrimps			Sculpin
PCBs												
CL2(08)	11.43	3.90	29.37	16.16	13.23	11.14				***14.21***	***7.7***	
CL3(18)			0.65		1.75					***1.20***	***0.5***	0.37
CL3(28)	0.44			2.69						***1.56***	***1.1***	
CL4(52)	1.26	0.15	0.15	0.24				0.26	1.38	***0.57***	***0.5***	1.24
CL4(44)	0.77	0.10	0.21	0.48			0.37	0.20	1.05	***0.45***	***0.3***	
CL4(66)	0.19	0.05		0.29			0.55	0.11	0.60	***0.30***	***0.2***	0.30
CL4(77)												
CL5(101)	0.91	0.12	0.17	0.42			1.10	0.60		***0.55***	***0.4***	1.74
CL5(105)							0.70	0.60	0.53	***0.61***	***0.1***	1.77
CL5(118)			0.06					0.17	0.38	***0.20***	***0.1***	0.70
CL5(126)												
CL6(128)												
CL6(138)	0.22	0.18	0.05	0.81			0.61	0.25	0.35	***0.35***	***0.2***	0.31
CL6(153)	0.28	0.24	0.21	0.25			0.55	0.24	0.56	***0.33***	***0.1***	0.45
CL7(170)												0.66
CL7(180)												0.43
CL7(187)		0.04	0.05				0.28			***0.12***	***0.1***	
CL8(195)												
CL9(206)												
CL10(209)												
Pesticides												
HEXACHLOROBENZENE	1.61	0.52	0.13	2.98	12.99	2.05	0.30	2.90	0.86	***2.71***	***3.8***	4.92
LINDANE					0.64		3.31	0.89	1.75	***1.65***	***1.0***	0.86
HEPTACHLOR									0.54	***0.54***	***0.0***	
ALDRIN												
HEPTACHLOREPOXIDE	0.44	0.21	0.50	0.53			2.85	0.73	0.27	***0.79***	***0.9***	0.64
CIS-CHLORDANE	1.75	0.47	0.04	0.84			2.49	1.30	0.63	***1.08***	***0.8***	1.51
TRANS-NONACHLOR	1.07	0.56	1.00	1.49		0.80	3.36	1.72	1.45	***1.43***	***0.8***	6.44
DIELDRIN	1.36	0.46	0.32	1.46		1.81	12.80	1.91	1.96	***2.76***	***3.8***	1.49
ENDRIN												
MIREX	0.46									***0.46***		
DDTs												
2,4-DDE				0.08			0.64	0.15		***0.29***	***0.3***	0.71
4,4-DDE	0.59	0.28	0.24	0.36				0.72	1.87	***0.68***	***0.6***	2.52
2,4-DDD												
4,4-DDD			0.12				1.10	0.28		***0.50***	***0.4***	
2,4-DDT												
4,4-DDT								0.20		***0.20***	***0.0***	
PCB Total :	**15.50**	**4.79**	**30.93**	**21.34**	**14.98**	**11.14**	**4.17**	**2.43**	**4.85**	***12.23***	***9.0***	**7.97**
Pesticide Total :	**7.28**	**2.51**	**2.35**	**7.74**	**13.62**	**4.65**	**26.87**	**10.80**	**9.34**	***9.46***	***7.1***	**19.08**
DDT Total :	**0.59**	**0.28**	**0.36**	**0.44**	**0.00**	**0.00**	**1.74**	**1.35**	**1.87**	***0.74***	***0.7***	**3.22**

A6-Polychlorinated Biphenyls and Pesticides in Sediments from the Beaufort Sea - Concentrations in ng/g dry weight

Compound	B-01	B-01	B-04	B-04	C-01	C-01	C-03	C-03	D-01	D-01	E-01	E-01	E-05	E-05	E-07	E-07	E-12	E-12	G-11	G-11	*Aver.*	*Std*	*Av.*	*Std*
PCBs		Cor		Cor		Cor		Cor		Cor		Cor		Cor		Cor		Cor		Cor			*Cor*	*Cor*
CL2(08)							0.14	0.14					0.17	0.17							***0.16***	***0.02***	***0.15***	***0.02***
CL3(18)					0.18	0.18	0.43	0.43	0.15	0.15	0.39	0.39	0.08	0.08					0.22	0.30	***0.24***	***0.14***	***0.30***	***0.14***
CL3(28)	0.13	0.20	0.32	0.33											0.15	0.16					***0.20***	***0.10***	***0.23***	***0.08***
CL4(44)	0.10	0.16	0.16	0.16	0.27	0.27	0.33	0.33	0.16	0.17	0.13	0.13	0.20	0.20	0.29	0.31	0.18	0.20	0.17	0.23	***0.20***	***0.07***	***0.23***	***0.08***
CL4(52)																								
CL4(66)	0.07	0.11	0.14	0.14	0.38	0.38									0.29	0.31	0.39	0.43	0.43	0.58	***0.28***	***0.15***	***0.33***	***0.18***
CL4(77)																								
CL5(101)			0.06	0.06	0.13	0.13	0.23	0.23	0.14	0.14	0.22	0.22									***0.16***	***0.07***	***0.17***	***0.08***
CL5(105)					0.18	0.18															***0.18***		***0.18***	
CL5(118)	0.18	0.28	0.14	0.14											0.17	0.18			0.83	1.12	***0.33***	***0.33***	***0.43***	***0.46***
CL5(126)																								
CL6(128)																								
CL6(138)			0.15	0.15															0.22	0.30	***0.19***	***0.05***	***0.22***	***0.10***
CL6(153)																								
CL7(170)	0.06	0.09	0.11	0.11			0.11	0.11					0.02	0.02	0.11	0.12	0.05	0.06	0.04	0.05	***0.07***	***0.04***	***0.08***	***0.04***
CL7(180)																								
CL7(187)											0.07	0.07									***0.07***		***0.07***	
CL8(195)							0.09	0.09											0.22	0.30	***0.16***	***0.09***	***0.16***	***0.12***
CL9(206)																			0.23	0.31	***0.23***		***0.31***	
CL10(209)									0.14	0.14			0.14	0.14			0.07	0.08	0.17	0.23	***0.13***	***0.04***	***0.15***	***0.08***
DDTs																								
2,4-DDE	0.21	0.33															0.34	0.38			***0.28***	***0.09***	***0.35***	***0.04***
4,4-DDE			0.29	0.29	0.20	0.20	0.50	0.50							0.18	0.19			0.17	0.23	***0.27***	***0.14***	***0.32***	***0.14***
2,4-DDD							0.23	0.23									0.35	0.39	0.50	0.67	***0.36***	***0.14***	***0.38***	***0.21***
4,4-DDD																								
2,4-DDT											0.26	0.26									***0.26***		***0.26***	
4,4-DDT	0.11	0.17									0.52	0.52									***0.32***	***0.29***	***0.35***	***0.25***
Other Pesticides																								
HEXACHLOROBENZENE																								
LINDANE	0.10	0.16			0.19	0.19	0.12	0.12					0.06	0.06	0.26	0.28	0.23	0.26			***0.16***	***0.08***	***0.17***	***0.08***
HEPTACHLOR											0.10	0.10									***0.10***		***0.10***	
ALDRIN																								
HEPTACHLOREPOXIDE					0.28	0.28															***0.28***		***0.28***	
CIS-CHLORDANE	0.21	0.33	0.14	0.14															0.09	0.12	***0.15***	***0.06***	***0.20***	***0.11***
TRANS-NONACHLOR																								
DIELDRIN																			0.16	0.22	***0.16***		***0.22***	
ENDRIN																								
MIREX																								
Grain Size Coefficient	0.64		0.98		0.99		0.99		0.97		1.00		0.99		0.92		0.90		0.74					
B-01 Cor = Grain size corrected value for site B-01																								
PCB Total:	**0.54**	**0.85**	**1.22**	**1.24**	**1.14**	**1.15**	**1.34**	**1.35**	**0.58**	**0.60**	**0.81**	**0.81**	**0.60**	**0.61**	**1.00**	**1.08**	**0.69**	**0.77**	**2.51**	**3.38**	***1.04***	***0.59***	***1.18***	***0.81***
Pesticide Total:	**0.63**	**0.99**	**0.43**	**0.44**	**0.67**	**0.68**	**0.86**	**0.86**	**0.00**	**0.00**	**0.88**	**0.88**	**0.06**	**0.06**	**0.44**	**0.48**	**0.92**	**1.02**	**0.92**	**1.24**	***0.58***	***0.34***	***0.66***	***0.41***
DDT Total:	**0.33**	**0.52**	**0.29**	**0.29**	**0.20**	**0.20**	**0.73**	**0.73**	**0.00**	**0.00**	**0.78**	**0.78**	**0.00**	**0.00**	**0.18**	**0.19**	**0.69**	**0.77**	**0.67**	**0.90**	***0.39***	***0.30***	***0.44***	***0.34***

A8a-NST Alaska Data - Metals in Sediments - Concentrations in ppm, except for Al, Fe, and Si in %

SITE	NO	GRNSIZE	Ag	Al%	As	Cd	Cr	Cu	Fe%	Hg	Mn	Ni	Pb	Sb	Se	Si%	Sn	Tl	Zn
BEAOP	1	0.61	0.13	4.39	2.33	0.32	70.85	18.29	2.49	0.20	392.50	23.11	14.02	0.53	0.41	30.15	1.07	0.31	80.98
Std		0.24	0.05	1.16	2.04	0.14	15.87	6.45	0.70	0.08	141.31	17.53	3.10	0.23	0.20	8.04	0.92	0.15	24.46
BEAPB	2	0.48	0.17	3.47	1.34	0.26	58.53	11.83	1.99	0.09	326.67	17.79	7.88	0.70	0.32	28.05	1.15	0.26	72.23
Std		0.20	0.06	0.29	0.32	0.07	16.28	4.27	0.22	0.02	109.72	11.37	3.79	0.20	0.07	2.71	1.31	0.08	12.38
AV. Beauf		**0.55**	**0.15**	**3.93**	**1.83**	**0.29**	**64.69**	**15.06**	**2.24**	**0.14**	**359.58**	**20.45**	**10.95**	**0.61**	**0.37**	**29.10**	**1.11**	**0.29**	**76.61**
Std		**0.09**	**0.03**	**0.65**	**0.71**	**0.04**	**8.71**	**4.57**	**0.35**	**0.08**	**46.55**	**3.77**	**4.34**	**0.12**	**0.06**	**1.48**	**0.06**	**0.03**	**6.19**
BERDH	3	0.71	0.11	5.23	2.22	0.70	30.67	49.67	3.75	0.24	736.00	5.13	12.93	0.72	0.70	22.90	2.77		85.33
Std		0.07	0.05	1.84	1.54	0.04	1.53	3.51	0.23	0.05	136.72	0.24	0.15	0.08	0.19	0.70	0.41		3.51
BERPM	4	0.08	0.06	8.51	1.67	0.43	63.00	13.33	6.43	0.06	1246.67	5.82	9.84	0.84	0.06	25.43	3.37		100.67
Std		0.03	0.04	0.94	0.29	0.11	17.35	1.15	0.88	0.01	135.77	1.26	0.85	0.04	0.00	1.00	0.30		11.37
BOCBP	5	0.57	0.29	7.03	1.90	0.44	52.67	22.00	3.69	0.04	839.00	7.49	17.87	0.92	0.74	23.80	3.21		104.33
Std		0.16	0.11	0.99	0.28	0.01	16.56	5.29	0.19	0.02	16.52	0.97	3.09	0.16	0.10	1.84	0.46		7.51
CHKRD	6	0.19	0.01	3.70	5.69	0.00	213.33	10.00	2.66	0.02	494.67	32.63	8.49	0.16	0.17	34.93	2.10		51.00
Std		0.08	0.02	0.41	0.45	0.00	11.55	0.00	0.37	0.03	87.76	3.45	0.84	0.02	0.06	2.31	0.55		27.07
GOAKB	7	0.68	0.26	7.49	1.75	0.19	82.33	26.67	3.55	0.06	765.67	9.32	14.67	0.43	0.19	29.23	2.70		89.67
Std		0.05	0.07	0.41	0.71	0.04	6.03	4.51	0.08	0.02	18.56	0.48	0.76	0.06	0.02	0.90	0.19		5.03
LUTCR	8	0.94	0.24	6.51	1.54	0.64	72.13	28.83	5.39	0.14	970.67	17.12	18.27	1.06	0.43	25.37	1.57	0.69	180.17
Std		0.09	0.17	0.93	0.30	0.41	20.98	4.79	0.20	0.21	56.11	7.95	3.99	0.16	0.25	0.83	1.52	0.31	9.83
NAHES	9	0.78	0.30	5.94	1.01	1.09	23.27	9.80	4.50	0.23	782.67	11.57	43.30	0.89	0.87	25.17	0.07	0.52	191.33
Std		0.19	0.10	0.51	1.31	0.23	2.40	0.35	0.28	0.15	89.54	1.91	9.12	0.05	0.40	1.72	0.12	0.11	15.50
PVMC	10	1.00	0.13	8.78	25.67	0.12	156.67	65.50	6.07	0.03	1933.33	65.67	17.33	2.87	0.27	24.83	1.17	0.76	150.00
Std		0.00	0.01	0.29	2.25	0.03	13.66	4.09	0.22	0.02	355.90	7.12	0.82	1.02	0.23	0.41	0.25	0.18	10.95
PWSPV	11	0.99	0.36	8.15	9.74	0.21	148.33	59.67	5.11	0.08	1025.67	16.60	23.13	1.36	0.41	26.87	2.79		150.00
Std		0.01	0.05	0.33	1.21	0.03	18.77	5.51	0.34	0.04	173.83	0.46	4.88	0.07	0.04	0.90	0.07		7.94
SKASR	12	0.63	0.42	8.36	3.45	0.40	43.00	16.90	3.67	0.08	670.67	4.28	52.20	0.96	0.15	29.13	2.76		169.33
Std		0.35	0.11	0.69	0.83	0.05	9.00	6.26	0.97	0.02	162.92	1.60	13.14	0.12	0.03	1.64	0.46		41.10
UISB	13	0.82	0.11	6.82	11.35	0.10	128.33	43.50	4.38	0.06	785.00	52.50	15.00	2.48	0.32	28.33	0.92	0.63	110.00
Std		0.07	0.01	0.66	1.47	0.02	11.69	4.72	0.23	0.01	50.89	5.79	2.90	0.95	0.07	1.03	0.33	0.20	8.94
AVER.		**0.65**	**0.20**	**6.49**	**5.36**	**0.38**	**87.93**	**28.92**	**4.13**	**0.10**	**843.78**	**20.69**	**19.61**	**1.07**	**0.39**	**27.25**	**1.97**	**0.53**	**118.08**
STD.		**0.28**	**0.12**	**1.83**	**6.94**	**0.30**	**56.65**	**19.36**	**1.36**	**0.08**	**412.96**	**19.02**	**13.30**	**0.78**	**0.25**	**3.22**	**1.04**	**0.21**	**45.00**
Median		**0.68**	**0.17**	**6.82**	**2.22**	**0.32**	**70.85**	**22.00**	**3.75**	**0.08**	**782.67**	**16.60**	**15.00**	**0.89**	**0.32**	**26.87**	**2.10**	**0.58**	**104.33**
Min.		**0.08**	**0.01**	**3.47**	**1.01**	**0.00**	**23.27**	**9.80**	**1.99**	**0.02**	**326.67**	**4.28**	**7.88**	**0.16**	**0.06**	**22.90**	**0.07**	**0.26**	**51.00**
Max.		**1.00**	**0.42**	**8.78**	**25.67**	**1.09**	**213.33**	**65.50**	**6.43**	**0.24**	**1933.33**	**65.67**	**52.20**	**2.87**	**0.87**	**34.93**	**3.37**	**0.76**	**191.33**

AV. Beauf= Average for the Beaufort Sea samples

Std= Standard deviation

AVER.= Total average; AVER. N= Total average after normalisation

SRD= Total standard deviation; STD.N. = Total standard deviation after normalization

Median N.= Median after normalization

Min.= Minimum value; Min. N.= Minimum values after normalization

Max.= Maximum value; Max. N.= Maximum value after normalization

N.= Normalization after grain size correction

SITE	NO	Ag N.	Al N.	As N.	Cd N.	Cr N.	Cu N.	Fe N.	Hg N.	Mn N.	Ni N.	Pb N.	Sb N.	Se N.	Si N.	Sn N.	Tl N.	Zn N.
BEAOP	1	0.21	71734	3.81	0.52	115.68	29.86	40711	0.33	641	37.74	22.89	0.86	0.67	492285	1.74	0.50	132.23
Std		0.08	18859	3.33	0.23	25.91	10.54	11486	0.13	231	28.62	5.07	0.38	0.33	131326	1.50	0.24	39.93
BEAPB	2	0.35	72360	2.78	0.54	122.06	24.67	41567	0.18	681	37.09	16.43	1.46	0.67	584923	2.41	0.55	150.63
Std		0.13	6071	0.67	0.15	33.95	8.91	4512	0.05	229	23.70	7.91	0.41	0.14	56430	2.73	0.16	25.81
AV. Beauf		**0.28**	**72047**	**3.30**	**0.53**	**118.87**	**27.27**	**41139**	**0.25**	**661**	**37.41**	**19.66**	**1.16**	**0.67**	**538604**	**2.07**	**0.52**	**141.43**
Std		0.10	442	0.72	0.01	4.51	3.67	605	0.11	29	0.46	4.57	0.43	0.00	65505	0.47	0.03	13.01
BERDH	3	0.15	73952	3.15	0.99	43.39	70.27	53059	0.34	1041	7.26	18.30	1.01	1.00	324011	3.92		120.74
Std		0.07	25967	2.17	0.05	2.16	4.97	3263	0.07	193	0.34	0.22	0.11	0.26	9904	0.58		4.97
BERPM	4	0.82	1096179	21.51	5.56	811.51	171.75	827823	0.79	16058	74.97	126.71	10.82	0.82	3276084	43.45		1296.69
Std		0.52	121677	3.73	1.43	223.48	14.87	112769	0.10	1749	16.22	10.91	0.56	0.05	129025	3.91		146.49
BOCBP	5	0.51	123204	3.33	0.77	92.30	38.56	64669	0.08	1470	13.13	31.31	1.61	1.29	417105	5.62		182.85
Std		0.20	17313	0.48	0.02	29.03	9.27	3283	0.03	29	1.70	5.41	0.27	0.17	32172	0.80		13.15
CHKRD	6	0.07	197333	30.33	0.00	1137.78	53.33	141867	0.11	2638	174.04	45.30	0.87	0.89	1863111	11.18		272.00
Std		0.12	21788	2.39	0.00	61.58	0.00	19581	0.18	468	18.42	4.48	0.08	0.31	123168	2.91		144.39
GOAKB	7	0.38	110499	2.58	0.28	121.41	39.32	52399	0.09	1129	13.74	21.63	0.63	0.28	431085	3.99		132.23
Std		0.10	6088	1.05	0.06	8.89	6.65	1192	0.03	27	0.70	1.12	0.08	0.02	13217	0.29		7.42
LUTCR	8	0.25	69490	1.64	0.68	76.98	30.77	57484	0.15	1036	18.27	19.49	1.13	0.46	270703	1.67	0.74	192.27
Std		0.19	9907	0.32	0.44	22.39	5.11	2098	0.23	60	8.48	4.26	0.17	0.27	8817	1.62	0.33	10.49
NAHES	9	0.38	75771	1.28	1.39	29.70	12.51	57435	0.29	999	14.76	55.26	1.14	1.11	321208	0.09	0.67	244.20
Std		0.13	6464	1.67	0.29	3.06	0.44	3635	0.20	114	2.44	11.64	0.07	0.50	22008	0.15	0.14	19.79
PVMC	10	0.13	87833	25.67	0.12	156.67	65.50	60667	0.03	1933	65.67	17.33	2.87	0.27	248333	1.17	0.76	150.00
Std		0.01	2927	2.25	0.03	13.66	4.09	2160	0.02	356	7.12	0.82	1.02	0.23	4082	0.25	0.18	10.95
PWSPV	11	0.37	82736	9.88	0.21	150.52	60.55	51854	0.08	1041	16.84	23.47	1.38	0.42	272629	2.83		152.21
Std		0.05	3357	1.22	0.03	19.05	5.59	3437	0.04	176	0.47	4.95	0.07	0.04	9095	0.07		8.05
SKASR	12	0.67	133521	5.50	0.64	68.65	26.98	58592	0.13	1071	6.83	83.34	1.53	0.23	1801394	4.41		270.34
Std		0.18	11068	1.32	0.08	14.37	9.99	15542	0.04	260	2.55	20.97	0.20	0.04	2297536	0.74		65.62
UISB	13	0.13	83299	13.87	0.12	156.82	53.16	53564	0.07	959	64.15	18.33	3.03	0.39	346232	1.12	0.77	134.42
Std		0.01	8010	1.80	0.03	14.29	5.77	2831	0.01	62	7.07	3.54	1.16		12621	0.41	0.25	10.93
AVER. N.		**0.34**	**175224**	**9.64**	**0.91**	**237.19**	**52.09**	**120130**	**0.20**	**2361**	**41.88**	**38.45**	**2.18**	**0.65**	**819162**	**6.43**	**0.31**	**263.91**
STD. N.		**0.22**	**279067**	**10.03**	**1.45**	**336.46**	**39.94**	**214129**	**0.20**	**4150**	**46.21**	**32.96**	**2.69**	**0.35**	**922279**	**11.48**	**0.35**	**314.78**
Median N.		**0.35**	**83299**	**3.81**	**0.54**	**121.41**	**39.32**	**57435**	**0.13**	**1041**	**18.27**	**22.89**	**1.38**	**0.67**	**417105**	**2.83**	**0.00**	**152.21**
Min. N.		**0.07**	**69490**	**1.28**	**0.00**	**29.70**	**12.51**	**40711**	**0.03**	**641**	**6.83**	**16.43**	**0.63**	**0.23**	**248333**	**0.09**	**0.00**	**120.74**
Max. N.		**0.82**	**1096179**	**30.33**	**5.56**	**1137.78**	**171.75**	**827823**	**0.79**	**16058**	**174.04**	**126.71**	**10.82**	**1.29**	**3276084**	**43.45**	**0.77**	**1296.69**

AV. Beauf= Average for the Beaufort Sea samples

Std= Standard deviation

AVER.= Total average; AVER. N= Total average after normalisation

SRD= Total standard deviation; STD.N. = Total standard deviation after normalization

Median N.= Median after normalization

Min.= Minimum value; Min. N.= Minimum values after normalization

Max.= Maximum value; Max. N.= Maximum value after normalization

N.= Normalization after grain size correction

							FISH LIVERS											
							(Benthic Surveillance Project Data)											
SITE	**No**	**Ag**	**As**	**Cd**	**Cr**	**Cu**	**Fe**	**Hg**	**Mn**	**Ni**	**Pb**	**Se**	**Sn**	**Zn**				
BEAOP Aver.	1	0.08	13.05	0.34	0.57	2.37	66.50	0.43	7.47	0.54	0.04	4.90	0.41	84.78				
Std		0.08	6.27	0.17	0.90	3.18	31.46	0.24	6.27	0.40	0.06	2.22	0.14	24.21				
BEAPB Aver.	2	0.14	24.78	0.76	0.22	7.78	47.33	0.24	5.00	0.71	0.03	6.41	0.60	127.82				
Std		0.09	8.53	0.37	0.15	6.73	24.88	0.27	2.63	0.14	0.04	2.31	0.16	23.67				
Av. Beaufort		**0.11**	**18.92**	**0.55**	**0.40**	**5.08**	**56.92**	**0.33**	**6.23**	**0.63**	**0.03**	**5.66**	**0.51**	**106.30**				
Std		**0.04**	**8.30**	**0.30**	**0.25**	**3.83**	**13.55**	**0.14**	**1.74**	**0.12**	**0.01**	**1.07**	**0.13**	**30.43**				
BERDH Aver.	3	0.13	10.17	0.03	1.00	NA	250.00	0.43	10.37	0.20	0.70	14.67	0.41	115.33				
Std		0.06	1.59	0.02	0.26	-	121.24	0.06	3.17	0.17	0.16	16.74	0.08	27.30				
BERPM Aver.	4	0.06	24.17	1.27	0.52	15.93	226.67	0.06	3.33	0.58	0.30	2.60	0.33	82.53				
Std		0.02	6.45	0.60	0.13	11.63	72.34	0.01	1.20	0.44	0.24	0.85	0.08	23.94				
BOCBP Aver.	5	0.07	84.83	1.50	0.16	18.40	233.67	0.05	1.73	0.49	NA	4.34	0.48	96.53				
Std		0.03	26.74	0.43	0.05	9.90	148.03	0.08	0.60	0.21	-	0.45	0.11	18.29				
GOAKB Aver.	7	0.17	69.67	1.56	0.17	49.33	651.00	0.27	6.87	0.24	0.01	17.47	0.55	117.17				
Std		0.21	32.50	1.13	0.11	51.87	381.18	0.18	1.37	0.13	0.02	6.99	0.17	27.57				
LUTCR Aver.	8	0.06	26.30	1.69	0.19	13.08	424.33	0.02	3.23	0.24	0.08	11.60	0.21	94.10				
Std		0.04	24.83	1.45	0.11	4.98	216.22	0.05	0.98	0.19	0.09	3.73	0.23	20.62				
NAHES Aver.	9	0.12	29.33	1.26	0.23	13.70	348.67	NA	3.73	0.66	0.25	11.54	0.72	99.60				
Std		0.06	10.02	0.71	0.11	3.80	159.00	-	1.82	0.36	0.09	4.20	0.68	27.94				
PWSPV Aver.	11	0.08	45.43	2.01	0.20	29.67	527.67	0.14	4.87	0.53	0.00	18.27	0.51	120.00				
Std		0.08	17.92	0.51	0.11	7.23	132.03	0.09	1.46	0.58	0.00	2.70	0.06	18.52				
SKASR Aver.	12	0.11	7.80	0.62	0.34	11.90	193.50	0.07	0.74	0.55	4.25	8.50	0.52	103.80				
Std		0.10	1.13	0.59	0.27	10.04	125.16	0.00	0.52	0.42	5.06	7.78	0.38	73.82				
Av.rest of Aka		**0.10**	**37.21**	**1.24**	**0.35**	**21.72**	**356.94**	**0.15**	**4.36**	**0.43**	**0.80**	**11.12**	**0.47**	**103.63**				
STD Aka		**0.04**	**27.61**	**0.63**	**0.29**	**13.57**	**164.99**	**0.15**	**3.06**	**0.18**	**1.54**	**5.73**	**0.15**	**13.04**				
AVERAGE Tot		**0.10**	**33.55**	**1.10**	**0.36**	**18.02**	**296.93**	**0.19**	**4.73**	**0.47**	**0.63**	**10.03**	**0.47**	**104.17**				
STD Tot		**0.04**	**25.69**	**0.64**	**0.27**	**13.92**	**192.86**	**0.16**	**2.87**	**0.18**	**1.37**	**5.56**	**0.14**	**15.38**				
Median		**0.09**	**25.54**	**1.26**	**0.23**	**13.70**	**241.83**	**0.14**	**4.30**	**0.54**	**0.08**	**10.02**	**0.49**	**101.70**				
Max		**0.17**	**84.83**	**2.01**	**1.00**	**49.33**	**651.00**	**0.43**	**10.37**	**0.71**	**4.25**	**18.27**	**0.72**	**127.82**				
Min		**0.06**	**7.80**	**0.03**	**0.16**	**2.37**	**47.33**	**0.02**	**0.74**	**0.20**	**0.00**	**2.60**	**0.21**	**82.53**				

Legend			NA=Not analyzed
Av. Beaufort = Average for the Beaufort Sea samples	STD Tot = Average for all the samples		
Std Beauf = Standard Deviation for the Beaufort Sea Samples	Median = Average for all the samples		
Av. rest of Aka = Average for the rest of Alaska samples	Max = Average for all the samples		
STD Aka = Standard Deviation for the Beaufort Sea Samples	Min = Average for all the samples		

MOLLUSKS
(Mussel Watch Project Data)

SITE	No	Ag	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Se	Sn	Zn	Al	Si	Sb	Tl
PVMC Aver.	10	0.03	12.28	2.48	3.11	11.18	1210	0.06	27.92	2.76	1.44	3.87	0.09	95.60	939	3026	0.08	0.00
Std		0.03	1.00	0.26	1.08	1.62	393	0.03	8.23	1.06	0.30	1.04	0.06	17.44	427	2010	0.12	
UISB Aver.	13	0.04	10.84	3.08	3.58	9.40	1021	0.09	24.11	2.03	1.05	4.01	0.04	81.72	1095	1372	4.01	0.00
Std		0.03	2.41	0.71	2.98	1.68	1000	0.02	16.15	1.11	0.52	0.56	0.04	9.10	1369	1054	0.56	
AVERAGE Tot		0.033	11.56	2.78	3.35	10.29	1116	0.08	26.02	2.40	1.24	3.94	0.07	88.66	1017	2199	2.05	0.00
STD Tot		0.005	1.02	0.43	0.33	1.25	134	0.02	2.70	0.52	0.27	0.10	0.04	9.81	110	1170	2.78	0.00
Median		0.03	11.56	2.78	3.35	10.29	1116	0.08	26.02	2.40	1.24	3.94	0.07	88.66	1017	2199	2.05	0.00
Max		0.04	12.28	3.08	3.58	11.18	1210	0.09	27.92	2.76	1.44	4.01	0.09	95.60	1095	3026	4.01	0.00
Min		0.03	10.84	2.48	3.11	9.40	1021	0.06	24.11	2.03	1.05	3.87	0.04	81.72	939	1372	0.08	0.00

MOLLUSKS -1995 Sampling
(Mussel Watch Project Data)

SITE	Ag	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Se	Sn	Zn	Al
KTMP	0.15	11.71	5.00	0.00	7.36	207	0.06	17.20	1.18	0.37	3.98	0.02	97.96	117
NBES	0.27	9.95	3.14	0.88	6.86	902	0.06	22.28	1.01	1.94	4.34	0.08	67.22	544
PVMC	0.00	10.43	2.32	2.70	10.52	1036	0.08	23.55	2.72	1.19	5.49	0.12	105.51	1048
PWSH	0.15	9.10	2.65	1.66	7.96	493	0.07	36.75	2.59	0.67	3.85	0.30	85.81	2098
PWKH	0.10	9.17	2.44	1.39	8.84	309	0.10	14.69	1.86	0.57	3.72	0.18	74.06	240
PWDI	0.00	9.43	3.28	2.29	8.51	475	0.10	17.21	1.93	0.78	4.48	0.18	115.59	462
UISB	0.00	8.33	2.96	8.84	11.83	3478	0.11	59.57	4.79	2.22	5.06	0.11	88.91	4309
GASL	0.00	8.54	3.10	2.39	9.35	713	0.11	15.69	1.60	0.74	4.68	0.11	81.73	467
GAWB	0.00	8.56	2.37	3.07	7.15	902	0.12	8.63	1.61	0.73	2.83	0.28	81.18	381
CIHS	0.00	10.86	1.94	5.18	7.80	2564	0.11	44.10	2.10	1.18	2.39	0.02	97.45	1727
GASH	0.00	6.53	3.17	1.00	7.42	149	0.05	7.39	0.89	0.26	2.39	0.22	93.15	88
AVERAGE Tot	**0.06**	**9.33**	**2.94**	**2.67**	**8.51**	**1021**	**0.09**	**24.28**	**2.02**	**0.97**	**3.93**	**0.15**	**89.87**	**1044**
STD Tot	**0.09**	**1.41**	**0.81**	**2.46**	**1.54**	**1051**	**0.02**	**16.11**	**1.09**	**0.62**	**1.04**	**0.09**	**14.01**	**1266**
Median	**0.00**	**9.17**	**2.96**	**2.29**	**7.96**	**713**	**0.10**	**17.21**	**1.86**	**0.74**	**3.98**	**0.12**	**88.91**	**467**
Max	**0.27**	**11.71**	**5.00**	**8.84**	**11.83**	**3478**	**0.12**	**59.57**	**4.79**	**2.22**	**5.49**	**0.30**	**115.59**	**4309**
Min	**0.00**	**6.53**	**1.94**	**0.00**	**6.86**	**149**	**0.05**	**7.39**	**0.89**	**0.26**	**2.39**	**0.02**	**67.22**	**88**

Legend

AVERAGE Tot = Average for all the samples

STD Tot = Average for all the samples

Median = Average for all the samples

Max = Average for all the samples

Min = Average for all the samples

A10a-NST Alaska Data - Polychlorinated Biphenyls in Sediments - Concentrations in ng/g dry weight

SITE	No	PCBs	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	Tot
		Cong.	8	18	28	44	52	66	101	105	107	118	126	128	138	153	170	180	187	195	206	209	Cong
BEAOP	1	Average		ND	0.50	1.83	ND	ND	0.73	ND		1.17		ND	1.00	0.23	ND	ND	ND	ND	ND	0.67	6.13
		Std			1.21	2.78			1.16			1.79			1.51	0.19						1.62	0.52
BEAPB	2	Average		ND	ND	0.42	0.17	0.17	0.12	ND		ND		ND	ND	0.08	ND	ND	ND	0.08	0.19	ND	1.23
		Std				1.01	0.40	0.40	0.09							0.07				0.20	0.19		0.11
Beauf Ave.					0.50	1.13	0.17	0.17	0.43			1.17			1.00	0.16				0.08	0.19	0.67	3.68
Std						1.00			0.44							0.11							3.47
BERDH	3	Average		1.33	ND	0.33	3.00	1.50	0.67	ND		ND		ND	3.50	3.33	0.67	1.50	1.00	0.23	ND	0.07	17.13
		Std		2.31		0.58	4.36	1.50	1.15						1.32	3.06	0.58	1.32	1.00	0.40		0.12	1.21
BERPM	4	Average		ND	2.33	1.33	ND	ND	ND	0.67		0.67		ND	3.47	3.20	ND	ND	ND	ND	0.17	ND	11.83
		Std			4.04	1.15				1.15		1.15			4.01	4.16					0.29		1.32
BOCBP	5	Average		1.00	ND	ND	3.00	0.67	ND	ND		0.67		0.67	5.67	1.33	1.00	ND	ND	0.33	ND	ND	14.33
		Std		1.73			3.00	1.15				1.15		1.15	3.51	2.31	1.73			0.58			1.71
CHKRD	6	Average		ND	ND	0.33	0.67	1.33	ND	0.83		0.83		0.53	1.20	0.40	ND	0.20	0.13	1.67	ND	ND	8.13
		Std				0.58	1.15	0.58		1.04		0.15		0.50	0.72	0.36		0.35	0.23	0.58			0.49
GOAKB	7	Average		1.33	ND	1.00	ND	ND	0.67	ND		1.00		ND	1.33	0.67	0.20		ND	0.30	ND	ND	6.50
		Std		1.15		1.00			1.15			1.73			1.15	1.15	0.35			0.52			0.43
LUTCR	8	Average		0.83	ND	ND	ND	0.67	0.10	0.17		0.50		0.17	0.48	ND	ND	ND	ND	ND	ND	ND	2.92
		Std		2.02				1.00	0.24	0.40		1.21		0.40	0.81								0.28
NAHES	9	Average	ND	ND	ND	ND	ND	ND	0.33	ND		ND		ND	ND	ND	ND	ND	ND	ND	ND	ND	0.33
		Std							0.58														
PVMC	10	Average	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Std										0.00											
PWSPV	11	Average		ND	ND	0.67	ND	ND	ND	ND		1.33		ND	0.67	ND	ND	ND	ND	ND	ND	ND	2.67
		Std				0.58						1.15			1.15								0.38
SKASR	12	Average		ND	ND	1.00	0.33	0.33	ND	ND		0.13		ND	ND	ND	ND	ND	ND	ND	0.27	ND	2.07
		Std				1.73	0.58	0.58				0.23									0.46		0.34
UISB	13	Average	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Std																					
Rest of Alaska Ave				1.12	2.33	0.78	1.75	0.90	0.44	0.56		0.73		0.46	2.33	1.79	0.62	0.85	0.57	0.63	0.22	0.07	7.32
STD				0.25		0.40	1.45	0.49	0.28	0.35		0.38		0.26	1.93	1.39	0.40	0.92	0.61	0.69	0.07		5.96
Average Tot				1.12	1.42	0.86	1.43	0.78	0.44	0.56		0.79		0.46	2.16	1.32	0.62	0.85	0.57	0.52	0.21	0.37	6.66
STD Tot				0.25	1.30	0.53	1.44	0.53	0.29	0.35		0.38		0.26	1.84	1.39	0.40	0.92	0.61	0.65	0.05	0.42	5.64
Median				1.17	1.42	0.83	0.67	0.67	0.50	0.67		0.75		0.53	1.27	0.67	0.67	0.85	0.57	0.30	0.19	0.37	6.13
Max				1.33	2.33	1.83	3.00	1.50	0.73	0.83		1.33		0.67	5.67	3.33	1.00	1.50	1.00	1.67	0.27	0.67	17.13
Min				0.83	0.50	0.33	0.17	0.17	0.10	0.17		0.13		0.17	0.48	0.08	0.20	0.20	0.13	0.08	0.17	0.07	0.33

Legend

ND = below detection limits

Std = Standard deviation

PCBs Cong. = Polychlorinated biphenyls congeners

Tot Cong = Sum of the PCB congeners

SITE	No		DI	TRI	TET	PEN	HEX	HEP	OCT	NON	Total PCBs
BEAOP	1	Average	ND	6.67	8.33	4.83	10.17	12.00	1.95	0.33	**44.28**
		Std		3.45	6.36	5.30	6.87	6.71	1.69	0.81	**4.25**
BEAPB	2	Average	ND	4.42	5.83	1.50	2.67	3.92	0.67	0.18	**19.18**
		Std		1.62	4.65	1.88	0.96	1.56	0.75	0.18	**2.09**
				5.54	**7.08**	**3.17**	**6.42**	**7.96**	**1.31**	**0.25**	**31.73**
				1.59	**1.77**	**2.36**	**5.30**	**5.72**	**0.91**	**0.11**	**17.75**
BERDH	3	Average		7.33	16.00	5.83	19.33	8.50	1.83	ND	**58.83**
		Std		6.66	2.00	5.06	10.26	2.18	1.61		**6.58**
BERPM	4	Average		10.00	10.67	8.00	11.67	3.00	ND	0.17	**43.50**
		Std		6.24	7.02	5.20	7.51	5.20		0.29	**4.64**
BOCBP	5	Average		2.33	4.67	0.67	9.00	1.00	0.33	ND	**18.00**
		Std		2.52	4.16	1.15	1.73	1.73	0.58		**3.34**
CHKRD	6	Average		1.00	7.00	7.00	6.33	1.13	2.33	ND	**24.80**
		Std		1.73	2.65	2.00	2.08	0.76	0.58		**2.94**
GOAKB	7	Average		3.67	3.33	2.33	5.33	1.67	0.33	ND	**16.67**
		Std		5.51	4.93	4.04	6.11	2.89	0.58		**1.73**
LUTCR	8	Average		3.17	2.50	2.43	2.23	ND	ND	ND	**10.33**
		Std		4.84	1.84	2.00	1.43				**0.41**
NAHES	9	Average	ND	0.50	2.67	2.67	0.85	0.33	ND	ND	**7.02**
		Std		0.50	2.31	2.08	1.00	0.58			**1.17**
PVMC	10	Average	ND	0.67	0.21	0.50	0.17	0.05	0.03	ND	**1.63**
		Std		0.76	0.24	0.70	0.21	0.05	0.08		**0.26**
PWSPV	11	Average		2.00	3.00	3.33	2.33	ND	ND	ND	**10.67**
		Std		1.73	3.61	3.51	3.21				**0.61**
SKASR	12	Average		2.67	5.00	1.50	3.00	0.63	0.50	0.27	**13.57**
		Std		3.79	2.65	0.87	1.00	0.55	0.50	0.46	**1.72**
UISB	13	Average	ND	1.02	0.57	0.05	ND	0.03	0.08	0.00	**1.75**
		Std		1.65	1.06	0.12		0.08	0.13	0.00	**0.41**
				3.12	**5.06**	**3.12**	**6.02**	**1.82**	**0.78**	**0.15**	**18.80**
				2.99	**4.67**	**2.69**	**5.93**	**2.67**	**0.92**	**0.14**	**17.73**
Average Tot				**3.50**	**5.37**	**3.13**	**6.09**	**2.93**	**0.90**	**0.19**	**20.79**
STD Tot				**2.91**	**4.36**	**2.55**	**5.60**	**3.89**	**0.89**	**0.13**	**17.66**
Median				**2.67**	**4.67**	**2.43**	**4.17**	**1.13**	**0.50**	**0.18**	**16.67**
Max				**10.00**	**16.00**	**8.00**	**19.33**	**12.00**	**2.33**	**0.33**	**58.83**
Min				**0.50**	**0.21**	**0.05**	**0.17**	**0.03**	**0.03**	**0.00**	**1.63**
Legend											
Di = Dichlorobiphenyl			Pen = Pentachlorobiphenyl			Oct = Octochlorobiphenyl			ND= below detection limits		
Tri = Trichlorobiphenyl			Hex = Hexachlorobiphenyl			Non = Nonachlorobiphenyl			Std= Standard deviation		
Tet = Tetrachlorobiphenyl			Hep = Heptachlorobiphenyl			TPCBS = Sum of all the PCBS					

SITE	No	Pesticides	2DDE	4DDE	2DDD	4DDD	2DDT	4DDT	TDDTs	ALD	C/CDANE	T/NCHL	DIELD	HEPCHL	HEPEPO	HEXCHL	LIND	MIR	TPEST
BEAOP	1	Average	ND	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	0.33	ND	ND	**0.33**
		Std	ND	ND	ND	ND		ND								0.50			
BEAPB	2	Average	ND	ND	ND	ND		0.17	**0.17**	ND	ND	ND	ND	ND	0.08	0.22	0.20	0.06	**0.72**
		Std	ND	ND	ND	ND		0.40	**0.40**						0.18	0.34	0.30	0.14	**0.07**
Beauf. Ave.								**0.17**	**0.17**						**0.08**	**0.28**	**0.20**	**0.06**	**0.53**
Std																**0.08**			**0.27**
BERDH	3	Average	ND	ND	ND	1.83		ND	**1.83**	ND	ND	ND	ND	ND	ND	0.15	ND	ND	**1.98**
		Std	ND	ND	ND	2.02		ND								0.26			**1.19**
BERPM	4	Average	ND	ND	ND	4.67		ND	**4.67**	ND	ND	ND	ND	ND	ND	ND	1.00	ND	**5.67**
		Std	ND	ND	ND	8.08		ND									1.73		**2.59**
BOCBP	5	Average	ND	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	0.67	ND	ND	**0.67**
		Std	ND	ND	ND	ND		ND								1.15			
CHKRD	6	Average	ND	0.13	0.27	0.10		1.03	**1.53**	ND	ND	ND	ND	ND	ND	ND	0.27	ND	**1.80**
		Std	ND	0.23	0.46	0.17		0.87	**0.44**								0.46		**0.90**
GOAKB	7	Average	ND	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	0.73	0.70	ND	**1.43**
		Std	ND	ND	ND	ND		ND								0.12	0.17		**0.02**
LUTCR	8	Average	ND	0.83	ND	1.33		ND	**2.16**	ND	ND	ND	ND	ND	ND	0.30	ND	ND	**2.46**
		Std	ND	2.02	ND	2.01		ND	**0.35**							0.46			**1.32**
NAHES	9	Average	ND	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
		Std	ND	ND	ND	ND		ND											
PVMC	10	Average	ND	0.13	ND	0.17	0.03	0.10	**0.43**	ND	0.03	ND	ND	ND	ND	ND	0.13	ND	**0.60**
		Std	ND	0.18	ND	0.19	0.08	0.24	**0.06**		0.08						0.33		**0.21**
PWSPV	11	Average	ND	ND	ND	ND		ND	ND	ND	ND	ND	ND	0.33	ND	0.30	0.97	ND	**1.60**
		Std	ND	ND	ND	ND		ND						0.58		0.26	0.06		**0.38**
SKASR	12	Average	ND	ND	ND	1.00		ND	**1.00**	ND	ND	ND	ND	ND	ND	0.47	0.53	ND	**2.00**
		Std	ND	ND	ND	0.50		ND								0.50	0.47		**0.29**
UISB	13	Average	ND	0.17	ND	0.18	ND	ND	**0.35**	ND	ND	ND	ND	ND	ND	0.02	ND	ND	**0.37**
		Std	ND	0.41	ND	0.29	ND	ND	**0.01**							0.04			**0.24**
Rest of Alaska Ave				**0.32**	**0.27**	**1.33**	**0.03**	**0.57**	**1.71**		**0.03**			**0.33**		**0.38**	**0.60**		**1.86**
Std				**0.34**		**1.62**		**0.66**	**1.47**							**0.26**	**0.36**		**1.50**
Average Tot				**0.32**	**0.27**	**1.33**	**0.03**	**0.43**	**1.52**		**0.03**			**0.33**	**0.08**	**0.35**	**0.54**	**0.06**	**1.64**
STD Tot				**0.34**		**1.62**		**0.52**	**1.47**							**0.23**	**0.36**		**1.46**
Median				**0.15**	**0.27**	**1.00**	**0.03**	**0.17**	**1.27**		**0.03**			**0.33**	**0.08**	**0.30**	**0.53**	**0.06**	**1.52**
Max				**0.83**	**0.27**	**4.67**	**0.03**	**1.03**	**4.67**		**0.03**			**0.33**	**0.08**	**0.73**	**1.00**	**0.06**	**5.67**
Min				**0.13**	**0.27**	**0.10**	**0.03**	**0.10**	**0.17**		**0.03**			**0.33**	**0.08**	**0.02**	**0.13**	**0.06**	**0.33**
Legend																			
2DDE, 4DDE, 2DDD, 4DDD = DDT metabolites; TDDTs = Total DDTs; Ald = Aldrin; C/CDANE = cis-chlordane; T/NCHL = trans-Nonachlor; DIELD = Dieldrin; HEPCHL = Heptachlor;																			
HEPEPO = Heptachlor Epoxide; HEXCHL = Hexachlorbenzene; LIND = Lindane; Mir = Mirex; TPEST = Total Pesticides																			

						FISH LIVERS					
						(Benthic Surveillance Project Data)					
Site	NO	PCBs	DI	TRI	TET	PEN	HEX	HEP	OCT	NON	TPCBS
BEAOP	1	Average	162.00	68.17	128.00	328.50	315.33	59.00	8.83	3.00	991.83
		Std	134.86	37.77	64.99	189.81	150.09	19.40	4.92	3.29	529.77
BEAPB	2	Average	ND	31.60	25.60	31.40	71.00	46.00	3.20	3.80	212.60
		Std		33.78	14.84	24.42	45.38	26.92	3.83	5.40	90.92
Av. Beaufort			162.00	49.88	76.80	179.95	193.17	52.50	6.02	3.40	602.22
Std				25.86	72.41	210.08	172.77	9.19	3.98	0.57	551.00
BERDH	3	Average		40.00	97.67	233.33	1043.33	640.00	124.33	12.67	2191.33
		Std		19.92	45.54	77.67	237.98	122.88	36.14	11.15	523.27
BERPM	4	Average		10.00	22.00	31.00	39.00	23.33	0.67	0.67	126.67
		Std		5.57	5.20	3.61	3.00	2.08	1.15	1.15	14.84
BOCBP	5	Average		29.67	49.67	124.67	163.67	79.00	4.00	0.67	451.33
		Std		12.74	24.09	48.22	89.67	26.29	3.46	1.15	196.18
CHKRD	6	Average		8.00	72.33	74.33	58.33	18.67	ND	ND	231.67
		Std		2.65	50.66	17.62	31.07	3.79			99.68
GOAKB	7	Average		44.00	45.67	56.00	76.00	58.00	9.67	ND	289.33
		Std		11.53	3.79	15.13	12.12	14.00	4.73		29.14
LUTCR	8	Average	1.00	26.67	57.50	122.50	215.50	94.00	11.50	3.33	531.50
		Std	1.73	19.37	33.55	81.70	141.82	65.80	9.12	2.16	320.72
NAHES	9	Average	3.67	12.50	47.00	188.33	236.67	101.17	9.75	3.17	602.25
		Std	4.04	6.73	16.09	10.41	30.55	8.31	1.56	2.02	46.16
PWSPV	11	Average		38.33	40.33	60.33	74.33	45.00	9.67	0.33	268.33
		Std		23.86	32.50	34.50	37.07	21.93	4.93	0.58	153.05
SKASR	12	Average		42.00	95.67	147.33	190.67	74.67	12.00	3.00	565.33
		Std		19.52	51.05	96.03	134.24	63.13	13.75	1.00	367.21
Average Tot			55.56	31.90	61.95	127.07	225.80	112.62	19.36	3.40	587.47
STD Tot			92.19	17.69	33.06	93.13	285.30	176.87	37.08	3.72	585.53
Median			3.67	31.60	49.67	122.50	163.67	59.00	9.67	3.00	451.33
Max			162.00	68.17	128.00	328.50	1043.33	640.00	124.33	12.67	2191.33
Min			1.00	8.00	22.00	31.00	39.00	18.67	0.67	0.33	126.67
						MOLLUSKS					
						(Mussel Watch Project Data)					
			DI	TRI	TET	PEN	HEX	HEP	OCT	NON	TPCBs
PVMC	10	Average	9.33	15.52	13.62	5.48	2.55	2.43	ND	ND	48.93
		Std	13.20	12.94	7.61	6.37	1.86	3.44			
UISB	13	Average	6.48333	9.97	9.30	6.85	1.72	0.73	ND	0.67	35.71
		Std	9.16882	6.74	1.37	5.02	2.43	1.03		0.94	
Average Tot			7.91	12.74	11.46	6.16	2.13	1.58		0.67	42.32
STD Tot			2.02	3.92	3.05	0.97	0.59	1.21			9.35
Median			7.91	12.74	11.46	6.16	2.13	1.58		0.67	42.32
Max			9.33	15.52	13.62	6.85	2.55	2.43	0.00	0.67	48.93
Min			6.48	9.97	9.30	5.48	1.72	0.73	0.00	0.67	35.71
Legend											
Di = Dichlorobiphenyl			Pen = Pentachlorobiphenyl			Oct = Octochlorobiphenyl					
Tri = Trichlorobiphenyl			Hex = Hexachlorobiphenyl			Non = Nonachlorobiphenyl					
Tet = Tetrachlorobiphenyl			Hep = Heptachlorobiphenyl			TPCBS = Sum of all the PCBS					

PCBS CONGENERS IN ALASKAN MOLLUSKS

(Mussel Watch Project Data)

SITE	No	PCBs	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	PCB	Tot
		Cong.	8	18	28	44	52	66	101	105	118	128	138	153	170	180	187	195	206	209	Cong
PVMC	10	Av.	ND	ND	ND	ND	ND	ND	0.14	ND	ND	ND	0.63	ND	ND	0.07	ND	ND	ND	ND	0.83
		Std							0.33				1.41			0.12					
UISB	13	Av.	1.13	ND	ND	0.31	ND	0.71	ND	ND	ND	ND	1.33	ND	ND	0.12	ND	ND	ND	ND	3.59
		Std	2.52			0.69		1.50					2.80			0.27					
Average Tot													**0.98**			**0.09**					**2.21**
STD Tot													**0.49**			**0.04**					**1.95**

Legend

PCBs Cong. = Polychlorinated biphenyl congeners

ND = Not detected

Tot Cong. = Sum of the polychlorinated biphenyl congeners

PCBs IN ALASKAN MOLLUSKS 1995 SAMPLING

(Mussel Watch Project Data)

SITE	T1245	T1234	Penta
KTMP	0.00	0.00	0.00
NBES	0.00	0.00	0.00
PVMC	0.00	0.00	0.00
PWSH	0.13	0.00	0.00
PWKH	0.00	0.00	0.00
PWDI	0.13	1.27	0.31
UISB	0.23	0.00	0.00
GASL	0.14	0.00	0.00
GAWB	0.07	0.00	0.00
CIHS	0.11	0.00	0.00
GASH	0.18	0.00	0.00
AVERAGE Tot	**0.09**	**0.12**	**0.03**
STD Tot	**0.08**	**0.38**	**0.09**
Median	**0.11**	**0.00**	**0.00**
Max	**0.23**	**1.27**	**0.31**
Min	**0.00**	**0.00**	**0.00**

Legend

T1234 = Arochlor 1234

T1245 = Arochlor 1245

Penta= Pentachlorobiphenyl

A14a-NST Alaska Data - Chlorinated Pesticides in Biota - Concentrations in ng/g dry weight

											Fish Livers									
Site	NO		2DDE	4DDE	2DDD	4DDD	2DDT	4DDT	TDDTs	ALD	a/CHL	T/NCHL	TCdane	DIELD	HEPC	HEPE	HEXCHL	LIND	MIR	T Pest
BEAOP	1	Average	3.00	18.00	1.50	16.33		4.83	43.67	0.83	8.83	26.17	35.17	15.33	0.17	5.50	26.83	4.67	1.83	133.83
		Std	5.62	13.27	1.76	6.77		4.62	20.33	2.04	2.23	4.22		7.53	0.41	3.21	3.66	2.66	1.94	14.49
BEAPB	2	Average	0.60	9.80	ND	13.60		5.60	29.60	ND	11.20	27.80	39.00	13.00	ND	4.40	42.60	1.60	1.20	131.40
		Std	1.34	4.97		15.31		4.56	22.59		5.97	8.07		4.85		3.65	21.03	1.52	1.64	15.23
Beaufort Av.			1.80	13.90	1.50	14.97		5.22	36.63	0.83	10.02	26.98	37.08	14.17	0.17	4.95	34.72	3.13	1.52	132.62
Std			1.70	5.80		1.93		0.54	9.95		1.67	1.15	2.71	1.65		0.78	11.15	2.17	0.45	1.72
BERDH	3	Average	6.33	37.00	ND	65.00		ND	108.33	ND	10.67	16.33	27.00	12.00	ND	ND	1.33	ND	ND	148.67
		Std	10.97	9.85		31.00			35.10		9.71	3.21		11.53			2.31			44.28
BERPM	4	Average	ND	18.33	1.00	17.67		3.00	40.00	ND	14.33	17.33	32.00	1.67	0.33	1.00	11.67	4.00	1.67	92.00
		Std		4.04	1.73	8.14		2.65	6.56		4.73	1.15		2.89	0.58	1.73	2.89	6.93	1.53	12.87
BOCBP	5	Average	7.00	170.00	2.67	38.33		28.67	246.67	ND	36.00	35.67	71.67	9.00	ND	1.00	11.00	4.00	3.33	346.67
		Std	7.00	50.00	4.62	17.62		17.47	67.00		9.54	8.39		3.61		1.73	5.57	6.93	4.16	83.34
CHKRD	6	Average	1.00	9.67	2.33	2.33		1.67	17.00	ND	5.00	7.67	12.67	2.00	ND	3.00	10.33	4.67	3.33	53.00
		Std	1.73	7.51	2.08	2.52		2.08	14.42		0.00	3.79		2.00		0.00	0.58	4.16	4.16	4.99
GOAKB	7	Average	ND	28.67	ND	27.00		2.00	57.67	ND	9.33	19.33	28.67	2.33	ND	ND	5.67	3.33	2.00	99.67
		Std		7.23		5.29		2.00	10.79		2.89	0.58		2.08			3.06	5.77	1.73	20.08
LUTCR	8	Average	0.50	144.33	7.00	48.50		11.67	212.00	ND	17.17	33.00	50.17	6.17	ND	0.33	4.83	1.00	2.17	276.67
		Std	1.22	69.44	6.29	36.10		7.71	109.04		9.81	15.07		5.15		0.82	6.21	2.45	3.49	72.53
NAHES	9	Average	ND	167.33	6.50	29.50		8.67	212.00	ND	14.83	39.83	54.67	ND	ND	ND	ND	ND	ND	266.67
		Std		66.94	2.18	11.69		1.53	70.16		3.25	11.03								107.35
PWSPV	11	Average	ND	35.67	2.33	21.00		3.33	62.33	ND	10.67	19.00	29.67	3.00	ND	0.67	3.67	2.00	1.33	102.67
		Std		18.72	2.52	12.12		2.89	34.70		4.04	7.21		2.65		1.15	1.53	3.46	1.15	20.95
SKASR	12	Average	ND	86.00	9.33	46.67		26.00	168.00	ND	33.67	29.67	64.00	12.00	0.67	3.67	18.00	0.00	1.33	267.00
		Std	0.00	69.16	8.62	41.53		21.79	139.69		23.01	18.23		7.00	1.15	3.21	13.00	0.00	2.31	53.39
Rest of AKA Av			3.71	77.44	4.45	32.89		10.63	124.89		16.85	24.20	41.17	6.02	0.50	1.61	8.31	2.71	2.17	183.67
STD			3.43	66.18	3.13	18.87		10.91	86.18		10.80	10.70	19.69	4.44	0.24	1.37	5.42	1.75	0.86	105.69
Average Tot			3.07	65.89	4.08	29.63		9.54	108.84	0.83	15.61	24.71	40.42	7.65	0.39	2.45	13.59	2.81	2.02	174.38
STD Tot			2.94	64.56	3.08	18.38		9.89	85.01		10.06	9.65	17.71	5.24	0.25	1.95	12.67	1.71	0.81	96.77
Median			2.00	35.67	2.50	27.00		5.22	62.33	0.83	11.20	26.17	35.17	7.58	0.33	2.00	10.67	3.33	1.83	133.83
Max			7.00	170.00	9.33	65.00		28.67	246.67	0.83	36.00	39.83	71.67	15.33	0.67	5.50	42.60	4.67	3.33	346.67
Min			0.50	9.67	1.00	2.33		1.67	17.00	0.83	5.00	7.67	12.67	1.67	0.17	0.33	1.33	0.00	1.20	53.00
Legend																				
2DDE, 4DDE, 2DDD, 4DDD = DDT metabolites; TDDTs = Total DDTs; Ald = Aldrin; C/CDANE = cis-chlordane; T/NCHL = trans-Nonachlor; DIELD = Dieldrin; HEPCHL = Heptachlor;																				
HEPEPO = Heptachlor Epoxide; HEXCHL = Hexachlorbenzene; LIND = Lindane; Mir = Mirex; TPEST = Total Pesticides																				

A14b-NST Alaska Data - Chlorinated Pesticides in Biota - Concentrations in ng/g dry weight

SITE	No		2DDE	4DDE	2DDD	4DDD	2DDT	4DDT	TDDTS	ALD	Mollusks a/CHL	T/NCHL	TCdane	DIELD	HEPC	HEPE	HEXCHL	LIND	MIR	END	T Pest
PVMC	10	Average	0.04	1.19	0.00	0.08	0.21	0.33	1.86	0.10	0.72	0.27	1.00	0.36	0.00	0.05	0.48	1.71	0.00	0.04	4.36
PVMC		Std	0.11	1.29	0.00	0.20	0.57	0.88	0.45	0.25	1.01	0.42	0.32	0.55	0.00	0.13	0.46	1.84	0.00	0.08	0.56
UISB	13	Average	0.00	0.73	0.39	0.00	0.20	0.04	1.35	0.34	1.19	0.74	1.97	0.79	0.03	0.14	0.64	2.39	0.00	0.00	7.45
UISB		Std	0.00	0.69	1.02	0.00	0.52	0.09	0.29	0.89	1.68	1.12	0.43	1.29	0.09	0.38	0.92	3.00	0.00	0.00	0.85
Aver Tot			0.02	0.96	0.19	0.04	0.20	0.18	1.60	0.22	0.96	0.51	1.48	0.57	0.02	0.10	0.56	2.05	0.00	0.02	5.90
STD			0.03	0.32	0.27	0.05	0.01	0.21	0.36	0.17	0.33	0.33	0.69	0.31	0.02	0.07	0.11	0.48	0.00	0.03	2.19
Median			0.02	0.96	0.19	0.04	0.20	0.18	1.60	0.22	0.96	0.51	1.48	0.57	0.02	0.10	0.56	2.05	0.00	0.02	5.90
Max			0.04	1.19	0.39	0.08	0.21	0.33	1.86	0.34	1.19	0.74	1.97	0.79	0.03	0.14	0.64	2.39	0.00	0.04	7.45
Min			0.00	0.73	0.00	0.00	0.20	0.04	1.35	0.10	0.72	0.27	1.00	0.36	0.00	0.05	0.48	1.71	0.00	0.00	4.36

							Mussel Watch Project Data									
							Results until 1995									
SITE	No		Naph	Menap2	Menap1	tNaph	Biph	Dimeth	Acenthy	Acenthe	Trimeth	Fluor	Phenanth	Anthra	Mephen1	tPhe/Ant
PVMC	10	Average	29.30	19.54	9.98	**58.82**	5.87	6.22	1.81	0.52	2.81	2.33	14.93	3.40	4.48	**22.81**
PVMC		Std	53.06	33.13	13.55		6.44	9.20	1.79	1.36	2.55	2.28	15.00	3.20	5.16	
UISB	13	Average	54.35	37.28	17.02	**108.64**	13.99	8.37	ND	1.10	1.78	0.98	4.48	2.87	0.45	**7.80**
UISB		Std	109.28	82.21	34.14		26.86	19.00		2.90	3.56	1.47	5.28	7.12	0.60	
Av Tot			**41.82**	**28.41**	**13.50**	**83.73**	**9.93**	**7.30**	**1.81**	**0.81**	**2.29**	**1.65**	**9.70**	**3.14**	**2.46**	**15.30**
STD			**17.71**	**12.55**	**4.97**	**35.23**	**5.74**	**1.52**		**0.41**	**0.73**	**0.96**	**7.39**	**0.37**	**2.85**	**10.61**
Med			41.82	28.41	13.50	**83.73**	9.93	7.30	1.81	0.81	2.29	1.65	9.70	3.14	2.46	**15.30**
Max			54.35	37.28	17.02	**108.64**	13.99	8.37	1.81	1.10	2.81	2.33	14.93	3.40	4.48	**22.81**
Min			29.30	19.54	9.98	**58.82**	5.87	6.22	1.81	0.52	1.78	0.98	4.48	2.87	0.45	**7.80**
SITE	No		Fluorant	Pyrene	Benanth	Chrys	BenzBFl	BenzKFl	BenzFl	BenEpy	BenApy	Peryl	Indeno	Dibenz	Benzop	TPAHs
PVMC	10	Average	26.55	7.82	5.59	17.23	10.29	5.42	32.23	3.49	0.26	4.45	1.05	ND	1.29	**249.13**
PVMC		Std	28.10	8.21	6.90	19.53	9.66	3.70		3.74	0.69	11.26	1.51		2.11	**13.44**
UISB	13	Average	6.52	3.14	0.51	0.72	0.90	0.41	3.27	0.19	0.09	0.65	ND	ND	0.31	**261.48**
UISB		Std	11.76	5.20	0.72	1.00	1.07	0.45		0.46	0.22	1.73			0.69	**25.50**
Av Tot			**16.53**	**5.48**	**3.05**	**8.98**	**5.59**	**2.91**	**17.75**	**1.84**	**0.18**	**2.55**	**1.05**	ND	**0.80**	**255.30**
STD			**14.16**	**3.31**	**3.59**	**11.67**	**6.64**	**3.54**	**20.48**	**2.34**	**0.12**	**2.69**			**0.70**	**8.73**
Med			16.53	5.48	3.05	8.98	5.59	2.91	17.75	1.84	0.18	2.55	1.05		0.80	**255.30**
Max			26.55	7.82	5.59	17.23	10.29	5.42	32.23	3.49	0.26	4.45	1.05		1.29	**261.48**
Min			6.52	3.14	0.51	0.72	0.90	0.41	3.27	0.19	0.09	0.65	1.05		0.31	**249.13**
Legend																
Naph= Naphtalene;							Menap1= 1-Methylnaphtalene;						Fluorant= Fluoranthene;			
Menap2= 2-Methylnaphtalene;							Fluor= Fluorene;						Benapy= Benzo[a]pyrene;			
Dimeth= 2,6-Dimethylnaphtalene;							Biph = Biphenyl;						Peryl = Perylene;			
Chrys = Chrysene;							Phenanth= Phenanthrene ;						Benanth = Benzoanthracene;			
Benzfl= Benzofluorene;							Benepy = Benzo[e]pyrene;						Benzop = Benzopyrene;			
Benzobfl= Benzo[b]fluoranthene;							Benzokfl = Benzo[k]fluoranthene;						Dibenz= Dibenz[a,h]anthracene;			
Acenthy= Acenaphthylene;							Indeno = Indenopyrene;						Anthra= Anthracene ;			
Acenthe=Acenaphtene;							Mephen1= 1-Methylphenanthrene;						Trimeth= 1,6,7-Trimethylnaphtalene ;			
tPhen/Ant = Sum Phenanthrenes + Anthracenes;							tNaph = Total Naphthalenes;						TPAHs = Sum of all the PAHs;			
ND=Not Detected																

1995 SAMPLING ALASKAN MOLLUSKS

Mussel Watch Project Data

SITE	Dibenzt	C1Phen	C2Phen	C3Phen	C4Phen	C1DibT	C2DibT	C3DibT	C1FluPy	C1Chry	C2Chry
KTMP	1.76	31.92	54.10	45.67	46.52	15.44	47.16	57.30	24.18	11.27	29.51
NBES	5.76	45.66	42.78	56.67	51.21	9.82	16.81	39.05	71.49	27.38	23.68
PVMC	4.90	29.85	51.02	38.60	26.54	22.14	47.33	53.45	20.30	10.26	14.51
PWSH	1.27	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWKH	3.27	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWDI	3.51	36.07	44.16	63.21	49.00	ND	53.36	90.44	28.12	24.59	47.41
UISB	6.66	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00
GASL	2.58	25.68	53.50	109.72	90.16	12.92	59.47	114.38	32.32	33.83	58.06
GAWB	1.17	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CIHS	3.88	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
GASH	1.22	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Av Tot	**3.27**	**33.84**	**49.11**	**62.77**	**52.69**	**15.08**	**44.83**	**70.92**	**35.28**	**21.47**	**28.86**
STD	**1.90**	**7.60**	**5.30**	**27.92**	**23.14**	**5.24**	**16.46**	**30.73**	**20.73**	**10.33**	**21.27**
Med	**3.27**	**31.92**	**51.02**	**56.67**	**49.00**	**14.18**	**47.33**	**57.30**	**28.12**	**24.59**	**26.60**
Max	**6.66**	**45.66**	**54.10**	**109.72**	**90.16**	**22.14**	**59.47**	**114.38**	**71.49**	**33.83**	**58.06**
Min	**1.17**	**25.68**	**42.78**	**38.60**	**26.54**	**9.82**	**16.81**	**39.05**	**20.30**	**10.26**	**ND**

SITE	C3Chry	C4Chry	C1Naph	C2Naph	C3Naph	C4Naph	C1Fluor	C2Fluor	C3Fluor	LMWPAH	HMWPAH	TPAH
KTMP	ND	ND	15.05	ND	ND	ND	ND	ND	ND	68.58	60.93	**129.51**
NBES	ND	ND	16.53	ND	ND	ND	ND	ND	ND	209.90	409.49	**619.39**
PVMC	ND	ND	18.26	29.20	51.93	ND	13.34	42.83	76.54	86.31	73.09	**159.40**
PWSH	ND	ND	12.99	ND	ND	ND	ND	ND	ND	47.75	21.17	**68.92**
PWKH	ND	ND	13.00	ND	ND	ND	ND	ND	ND	68.60	37.04	**105.64**
PWDI	ND	ND	11.37	ND	ND	ND	ND	ND	ND	67.53	112.18	**179.71**
UISB	ND	ND	28.28	ND	ND	ND	ND	ND	ND	109.38	33.11	**142.49**
GASL	5.67	7.97	11.76	ND	ND	ND	ND	39.50	74.10	60.30	83.65	**143.95**
GAWB	ND	ND	7.27	ND	ND	ND	ND	ND	ND	45.26	19.09	**64.35**
CIHS	ND	ND	12.26	ND	ND	ND	ND	ND	ND	58.25	25.33	**83.58**
GASH	ND	ND	16.21	ND	ND	ND	ND	ND	ND	52.85	16.55	**69.40**
Av Tot	**5.67**	**7.97**	**14.82**	**29.20**	**51.93**		**13.34**	**41.17**	**75.32**	**79.52**	**81.06**	**160.58**
STD			**5.38**					**2.35**	**1.73**	**46.94**	**113.24**	**157.28**
Med	**5.67**	**7.97**	**13.00**	**29.20**	**51.93**		**13.34**	**41.17**	**75.32**	**67.53**	**37.04**	**129.51**
Max	**5.67**	**7.97**	**28.28**	**29.20**	**51.93**		**13.34**	**42.83**	**76.54**	**209.90**	**409.49**	**619.39**
Min	**5.67**	**7.97**	**7.27**	**29.20**	**51.93**		**13.34**	**39.50**	**74.10**	**45.26**	**16.55**	**64.35**

Legend

Dibenzt = Dibenzothiophene
C1Phen = C1-Phenanthrene
C2Phen = C2-Phenanthrene
C3Phen = C3-Phenanthrene
C4Phen = C4-Phenanthrene
C1DibT = C1-Dibenzothiophene
C2DibT = C2-Dibenzothiophene
C3DibT = C3-Dibenzothiophene
C1FluPy = C1-Fluopyrene
C1Chry = C1-Chrysene
C2Chry = C2-Chrysene
ND = Not Detected

C3Chry = C3-Chrysene
C4Chry = C4-Chrysene
C1Naph = C1-Naphthalene
C2Naph = C2-Naphthalene
C3Naph = C3-Naphthalene
C4Naph = C4-Naphthalene
C1Fluor = C1-Fluorene
C2Fluor = C2-Fluorene
C3Fluor = C3-Fluorene
LMWPAH = Low Molecular Weight Polyaromatic Hydrocarbons
HMWPAH = High Molecular Weight Polyaromatic Hydrocarbons
TPAH = Sum of all the PAHs

Appendix B
Beaufort Sea Figures

In all the figures of Appendix B, the triangles correspond to the position of the sites. The circles correspond to the concentrations of the element or compound. The size of the circle is proportional to the concentration of the element or compound in the sample. The scale varies and is given in each figure.

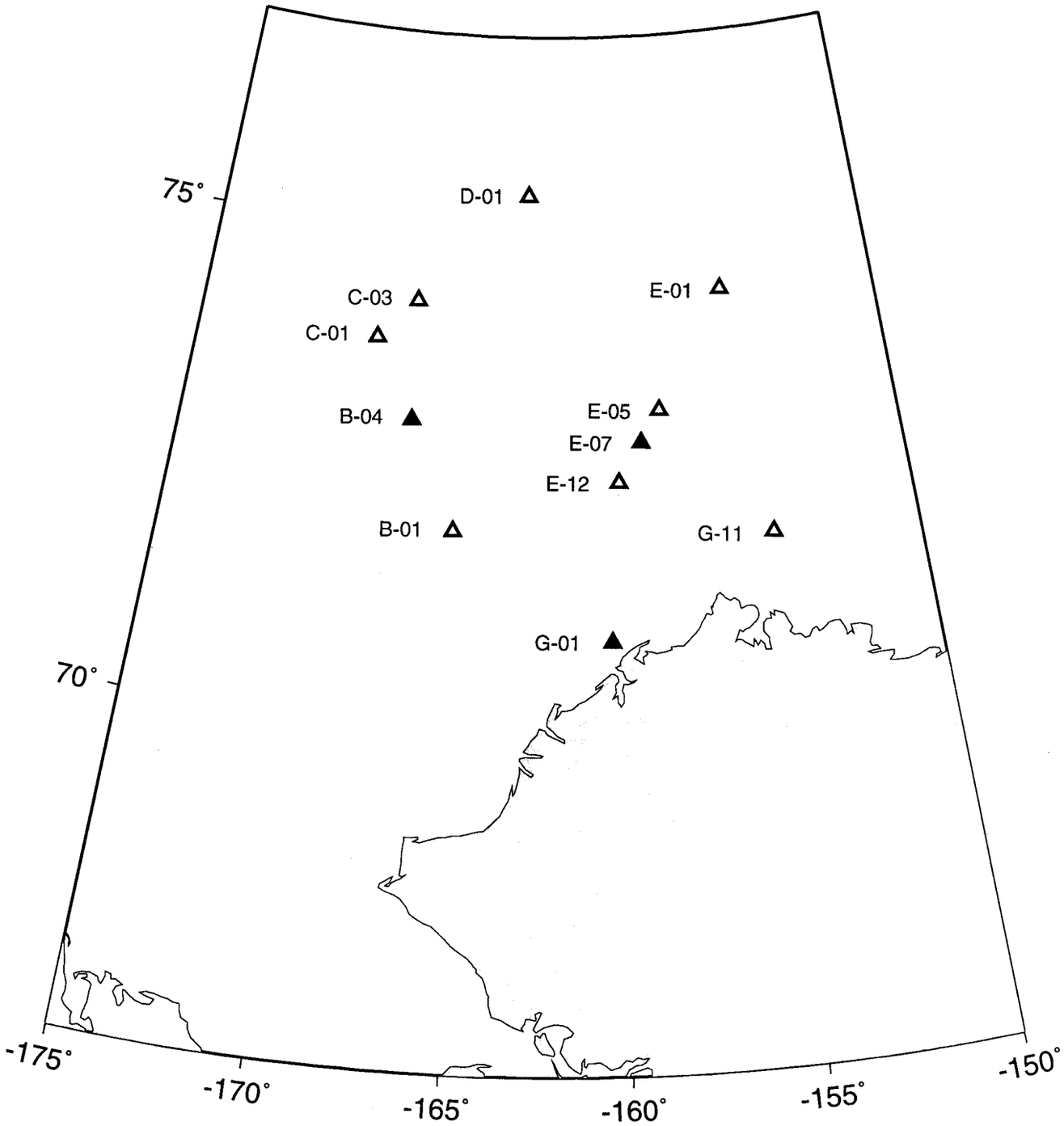
In figure B1, full triangles correspond to sites where biota and sediments were collected, empty symbols correspond to sites where sediments only were collected. Sediments were not collected at site G-01.

"Uncorrected": Raw data, uncorrected for grain size variability.

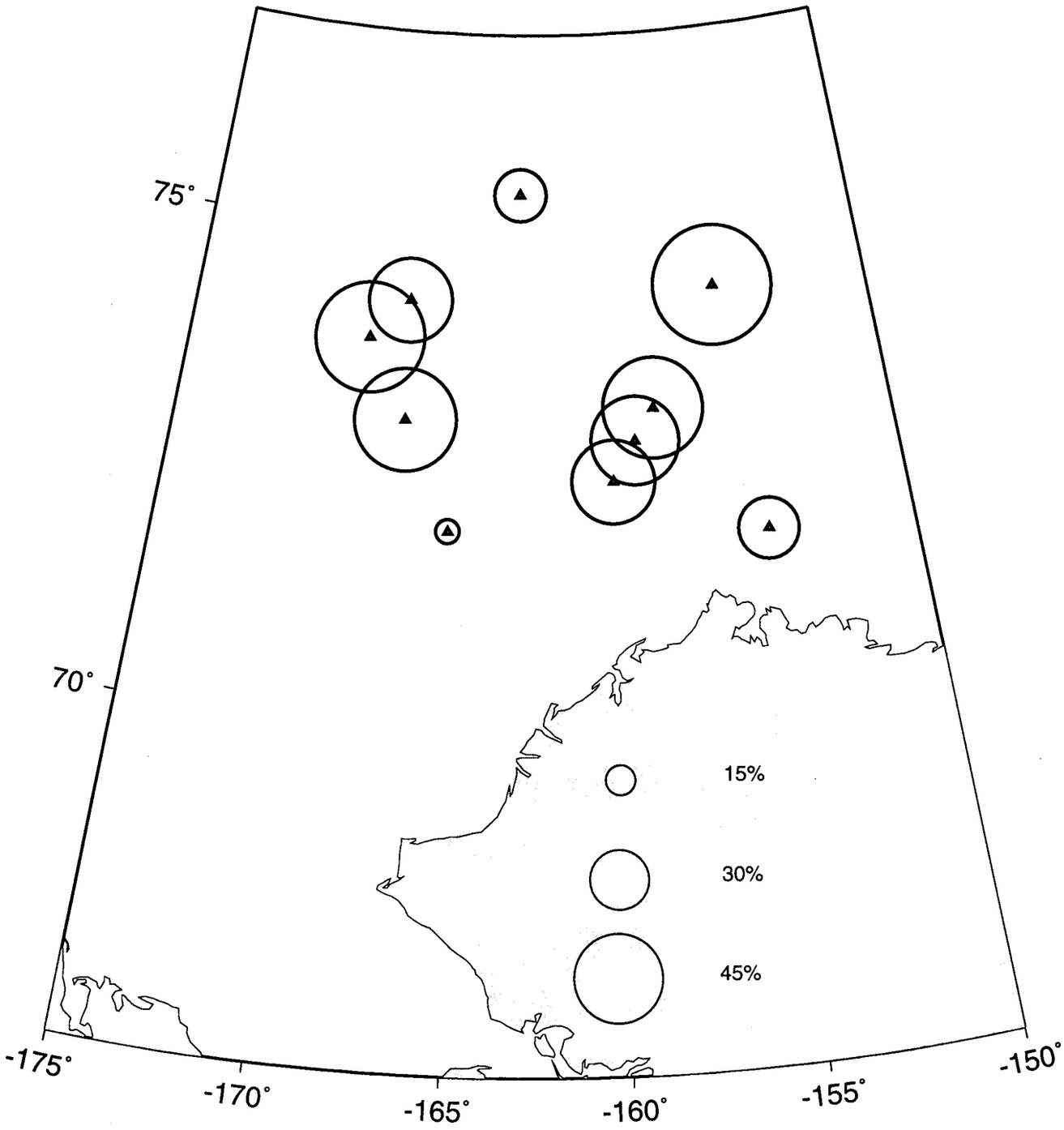
In B5, the data used to construct the figure were obtained after γ-counting

In B6, the data used to construct the figure were obtained after chemical separation and β– and γ-counting).

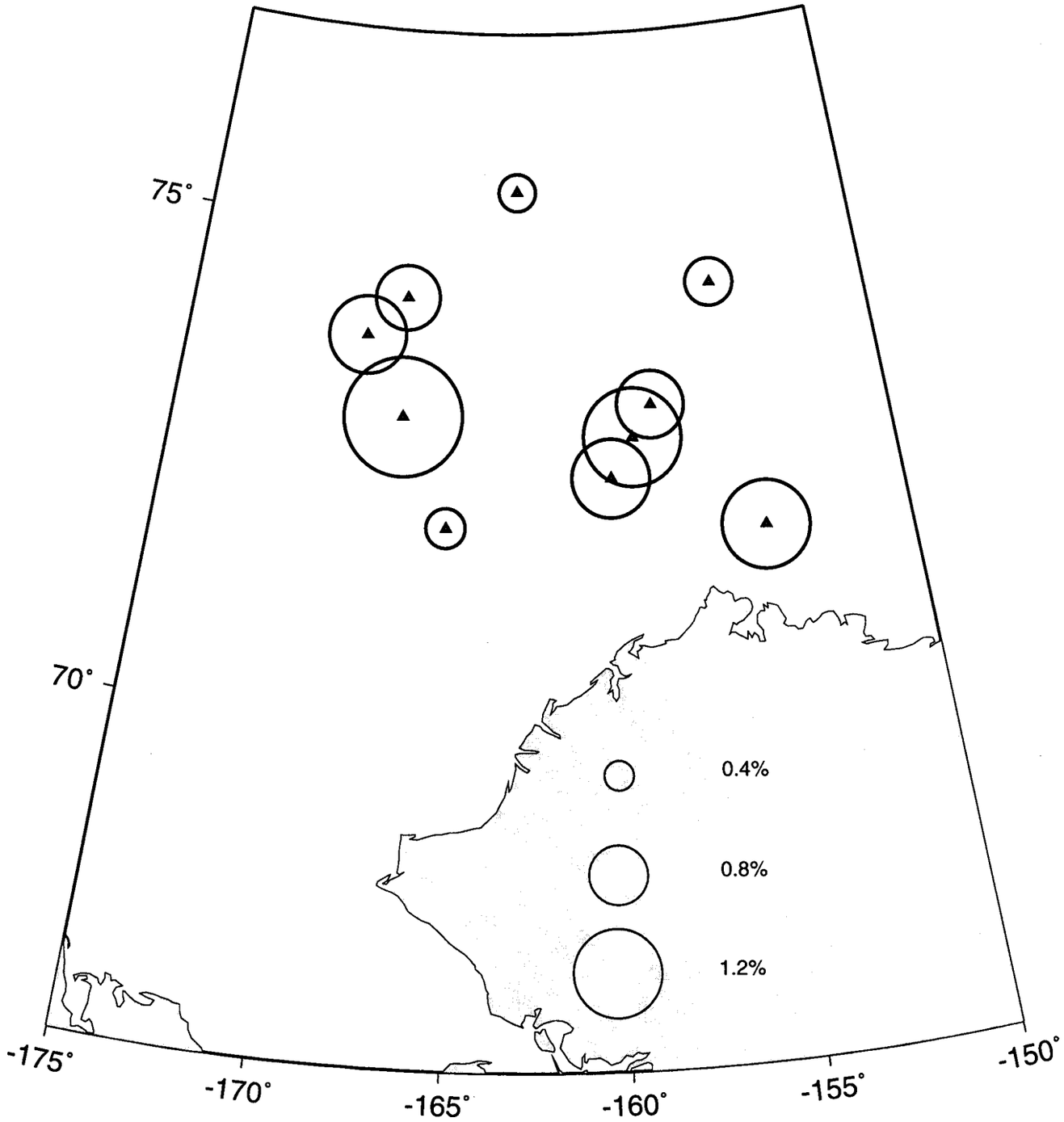
B1-Polar Star Sites



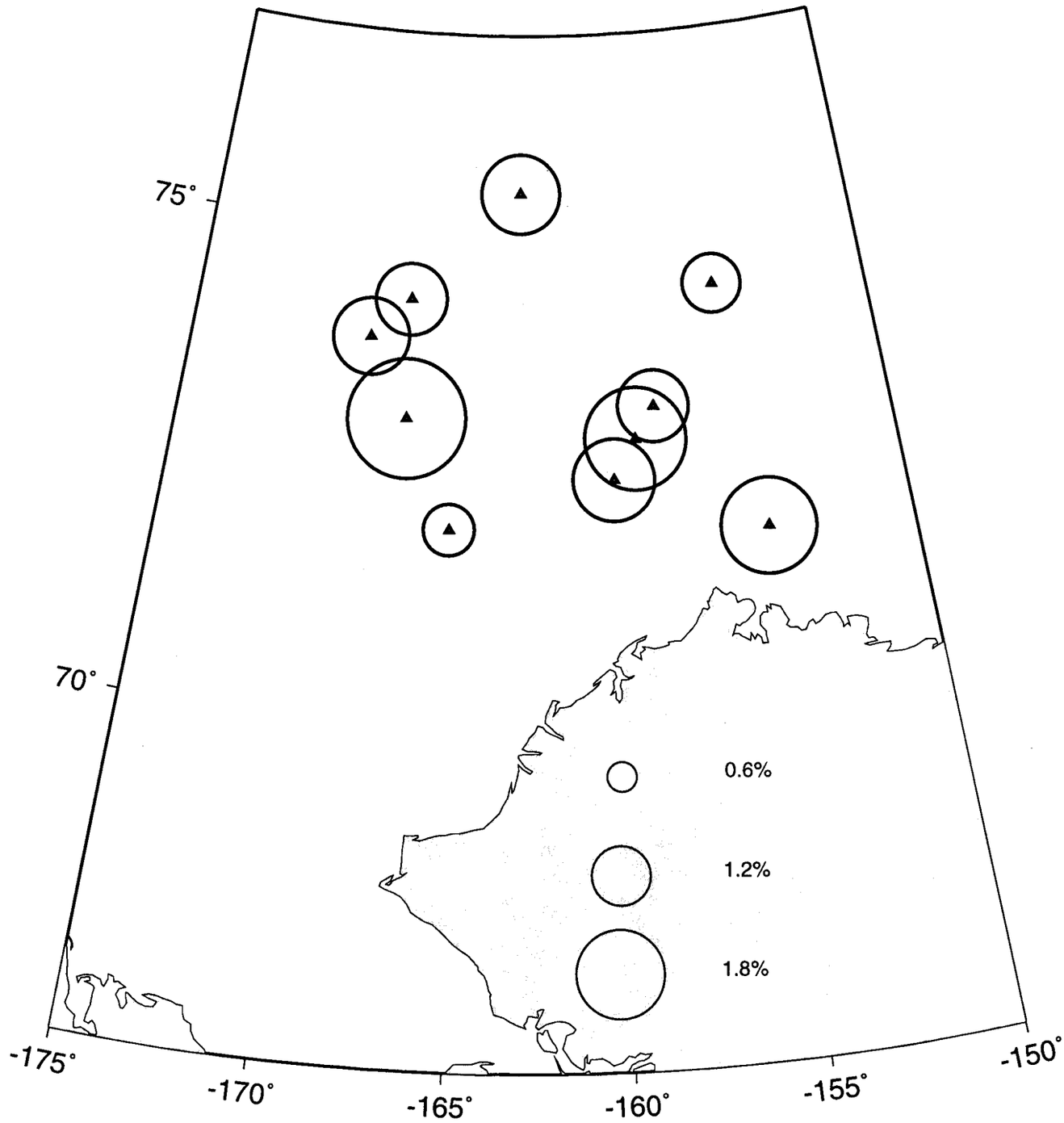
B2-Polar Star Sediments: Clay (uncorrected)



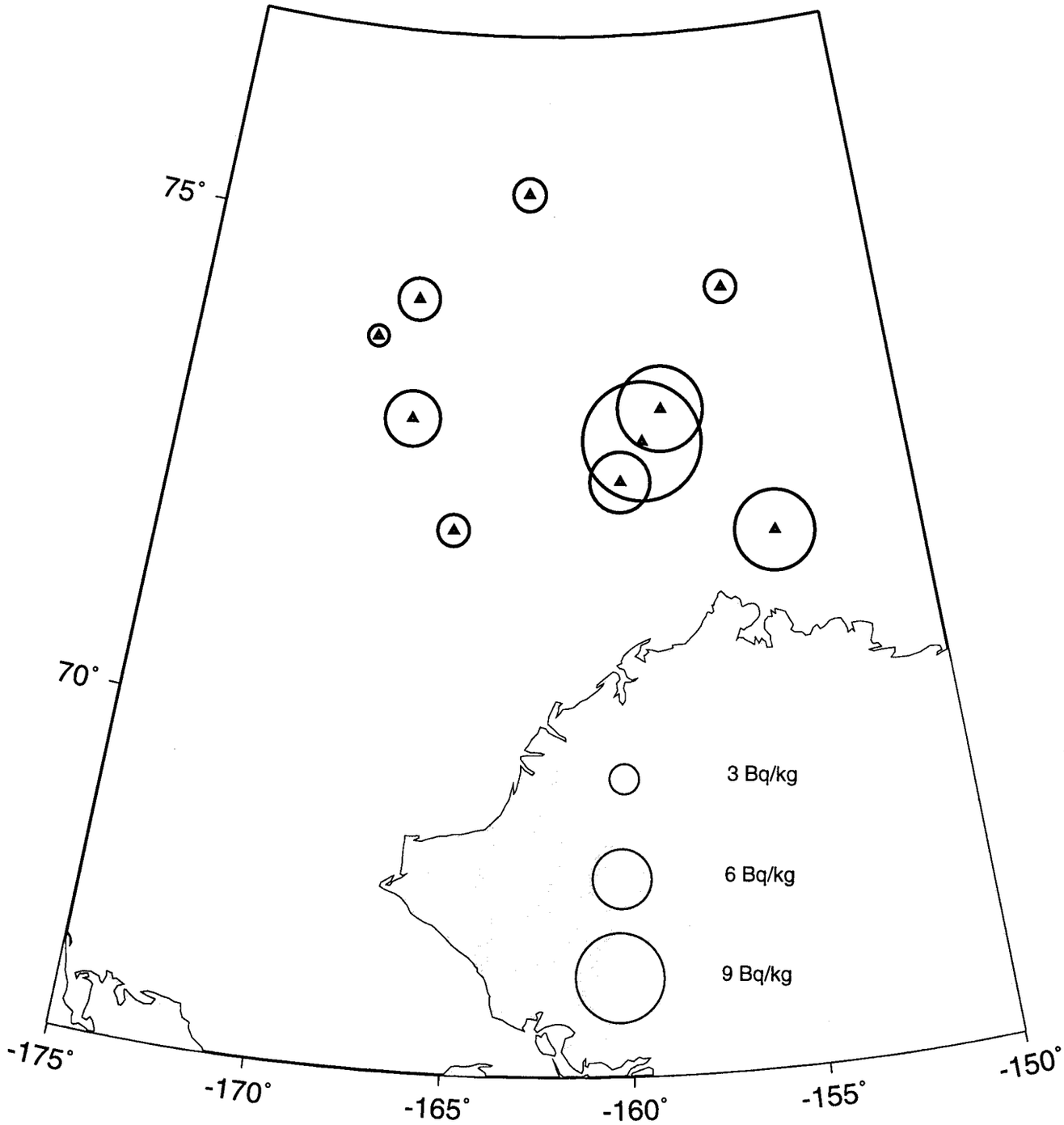
B3-Polar Star Sediments: TOC (uncorrected)



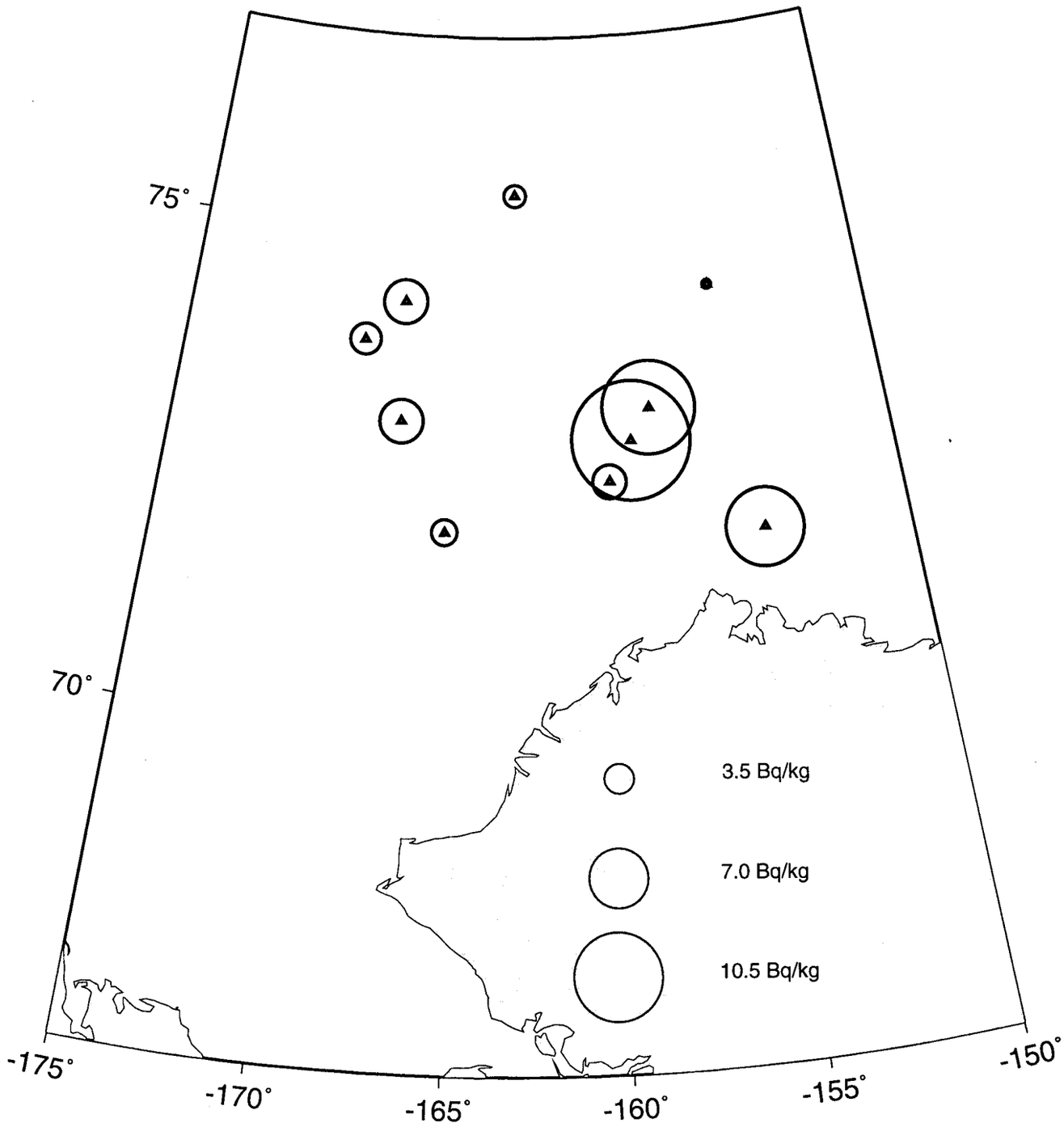
B4-Polar Star Sediments: TIC (uncorrected)



B5-Polar Star Sediments: 137-Cs (uncorrected)



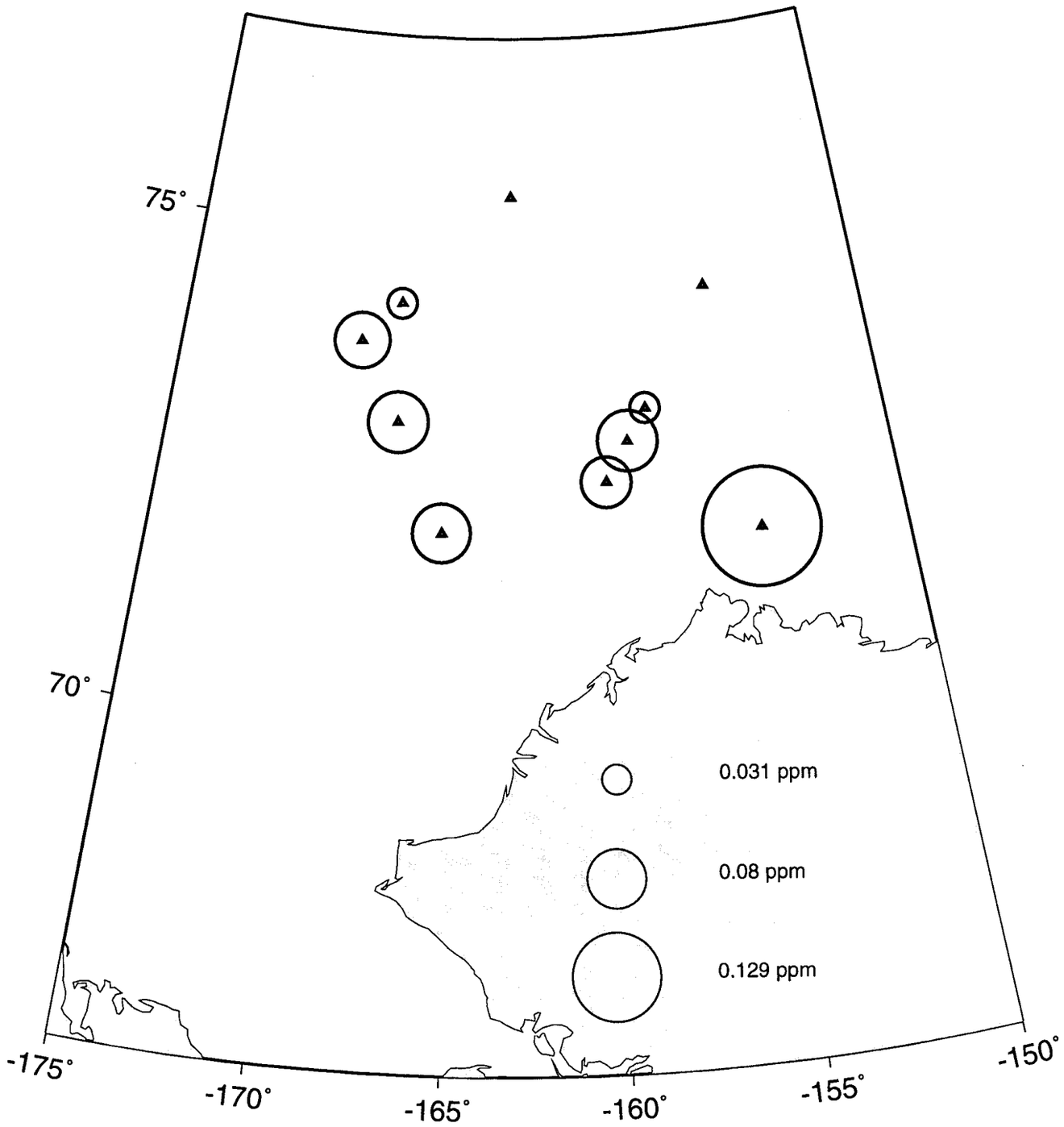
B6-Polar Star Sediments: 137-Cs** (uncorrected)



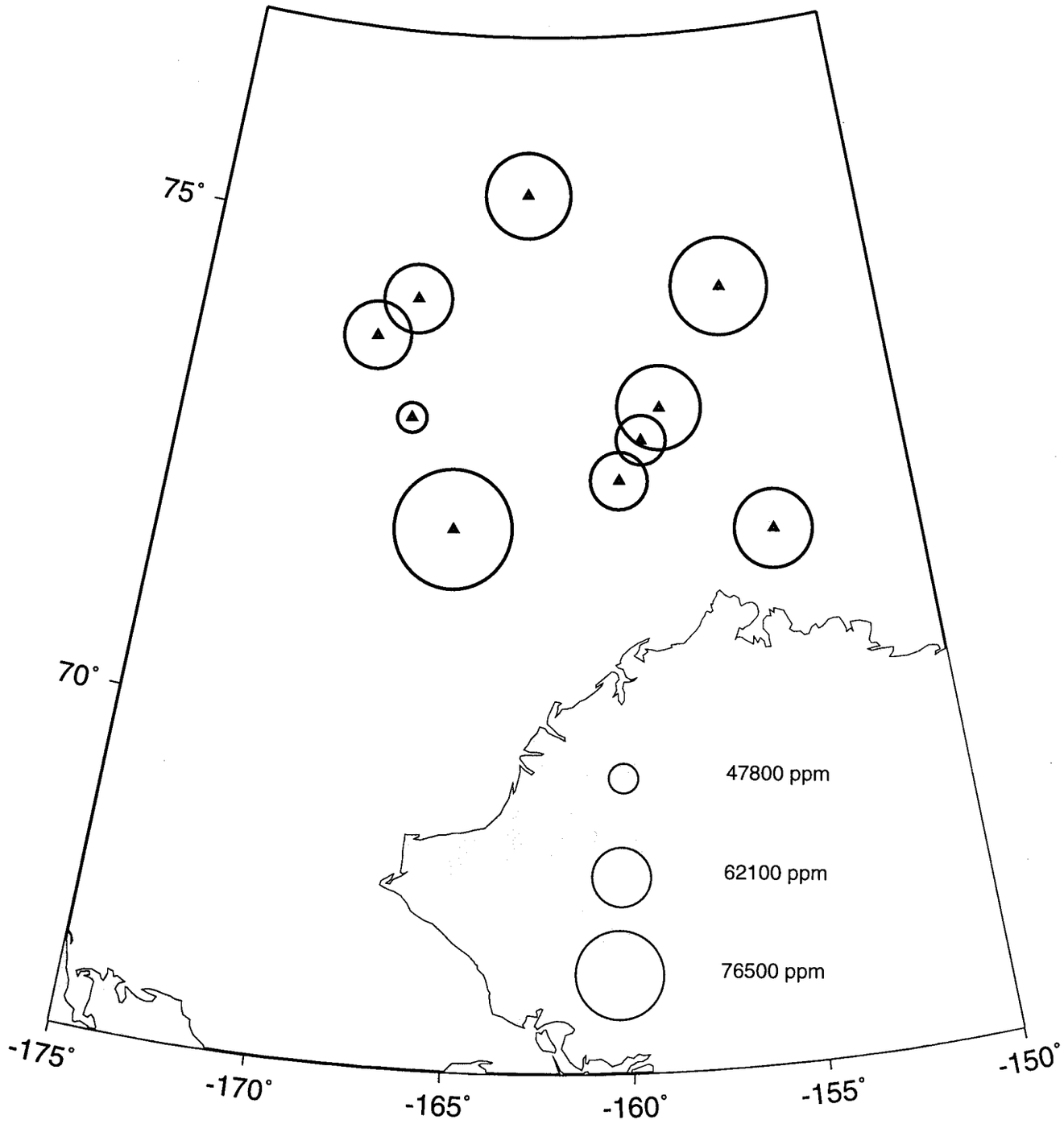
Trace Metals (Concentrations in ppm dry weight)

All the data used to construct these figures are concentrations corrected for grain size variability.

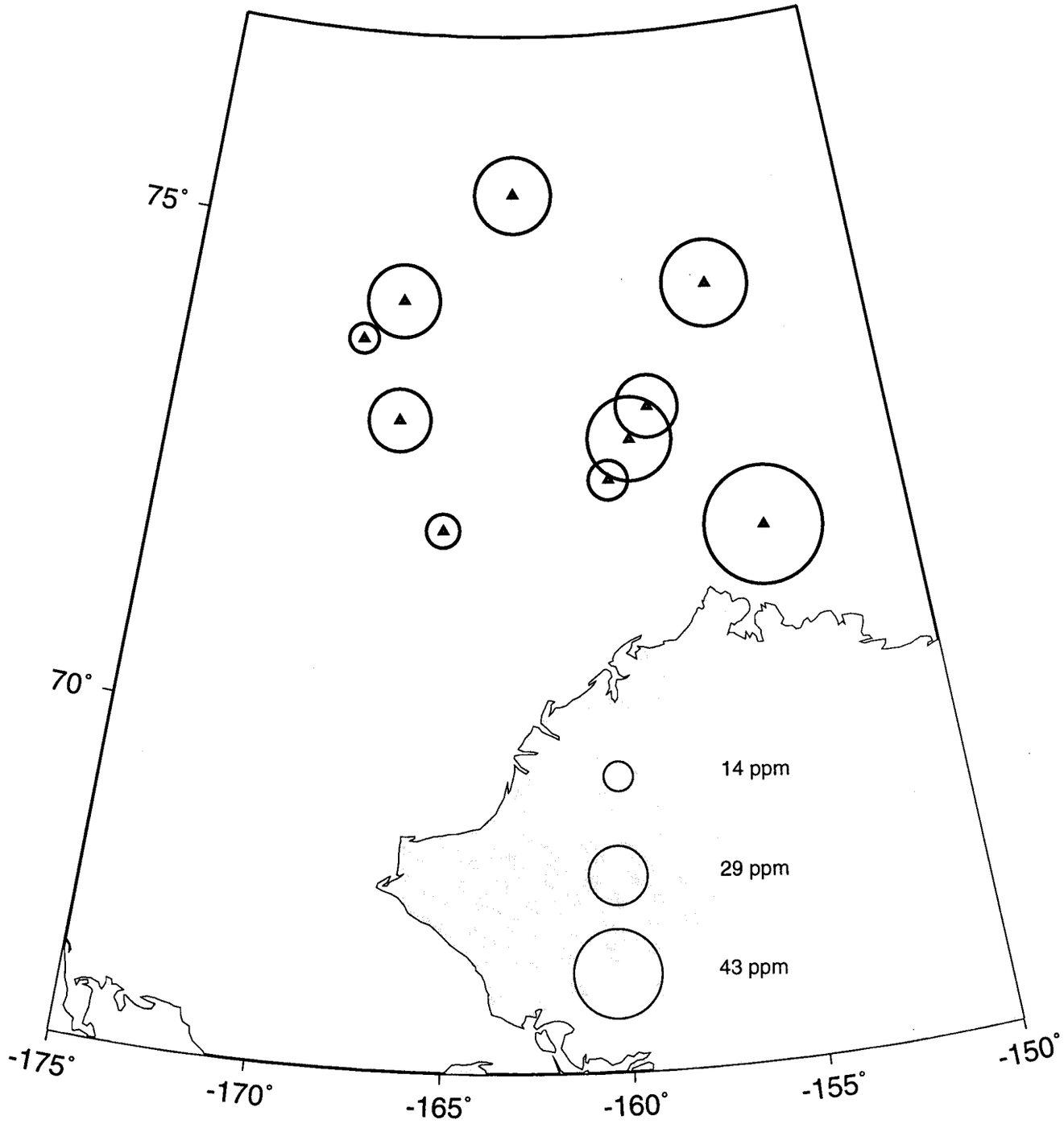
B7-Polar Star Sediments: Silver



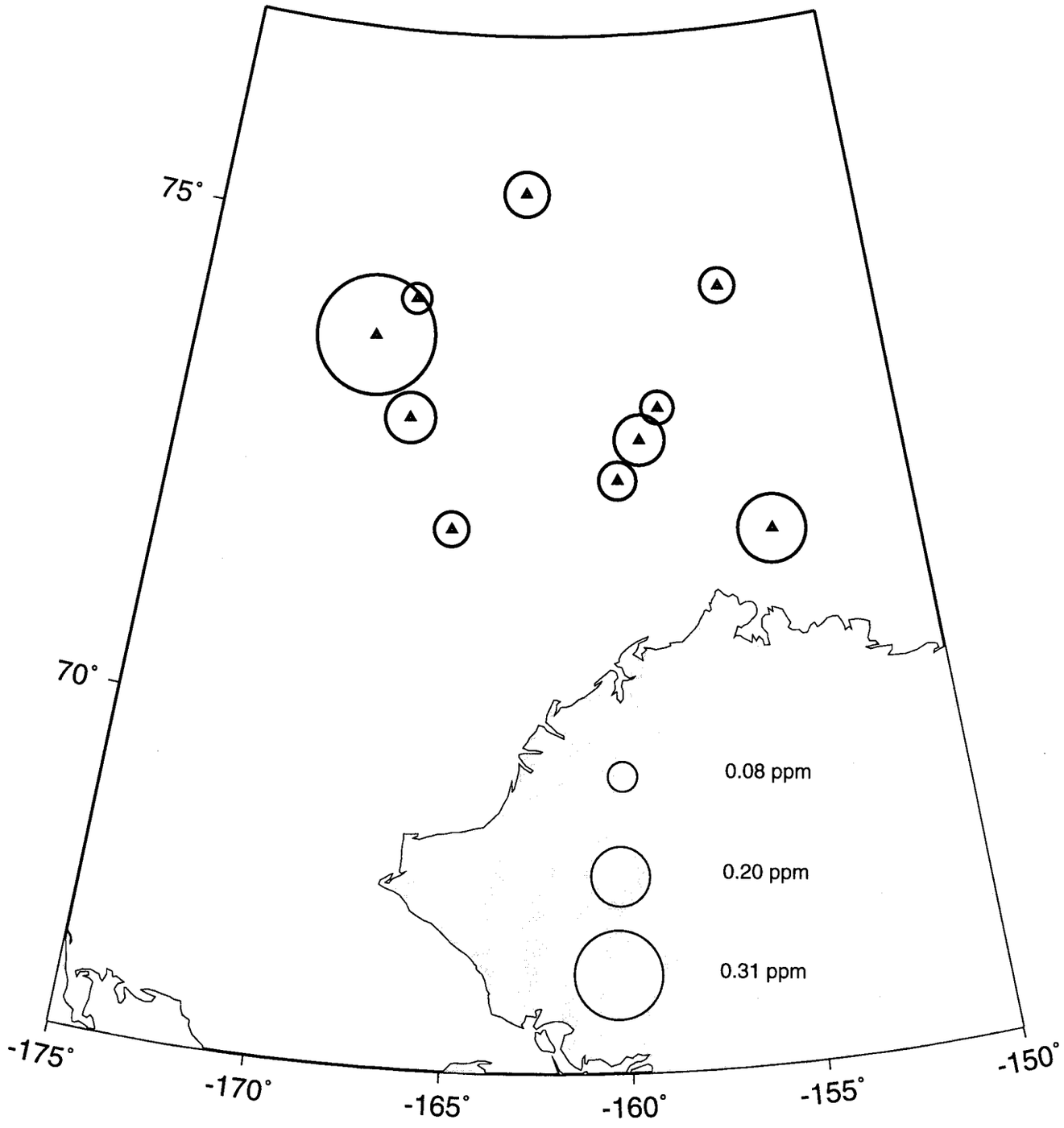
B8-Polar Star Sediments: Aluminum



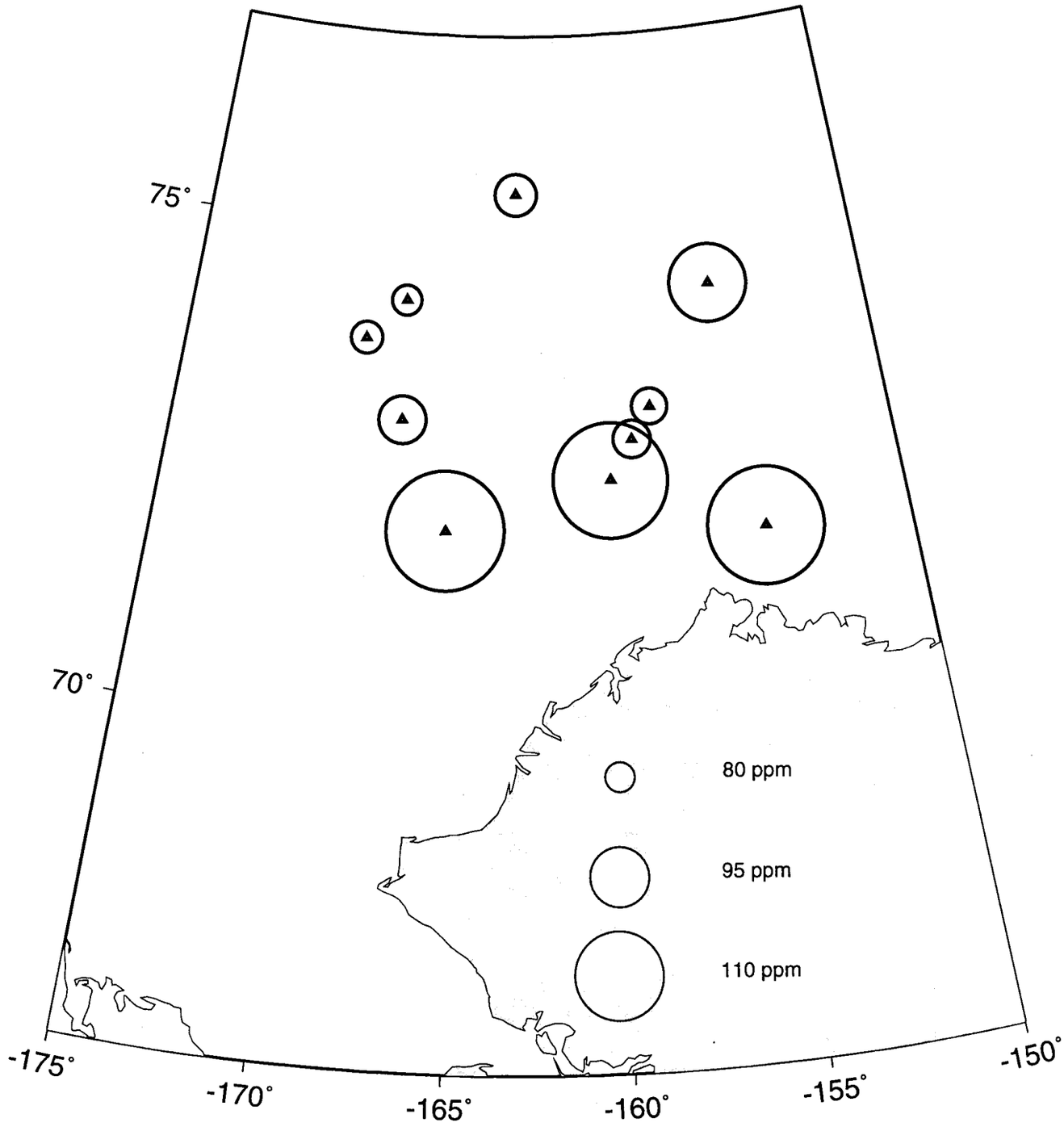
B9-Polar Star Sediments: Arsenic



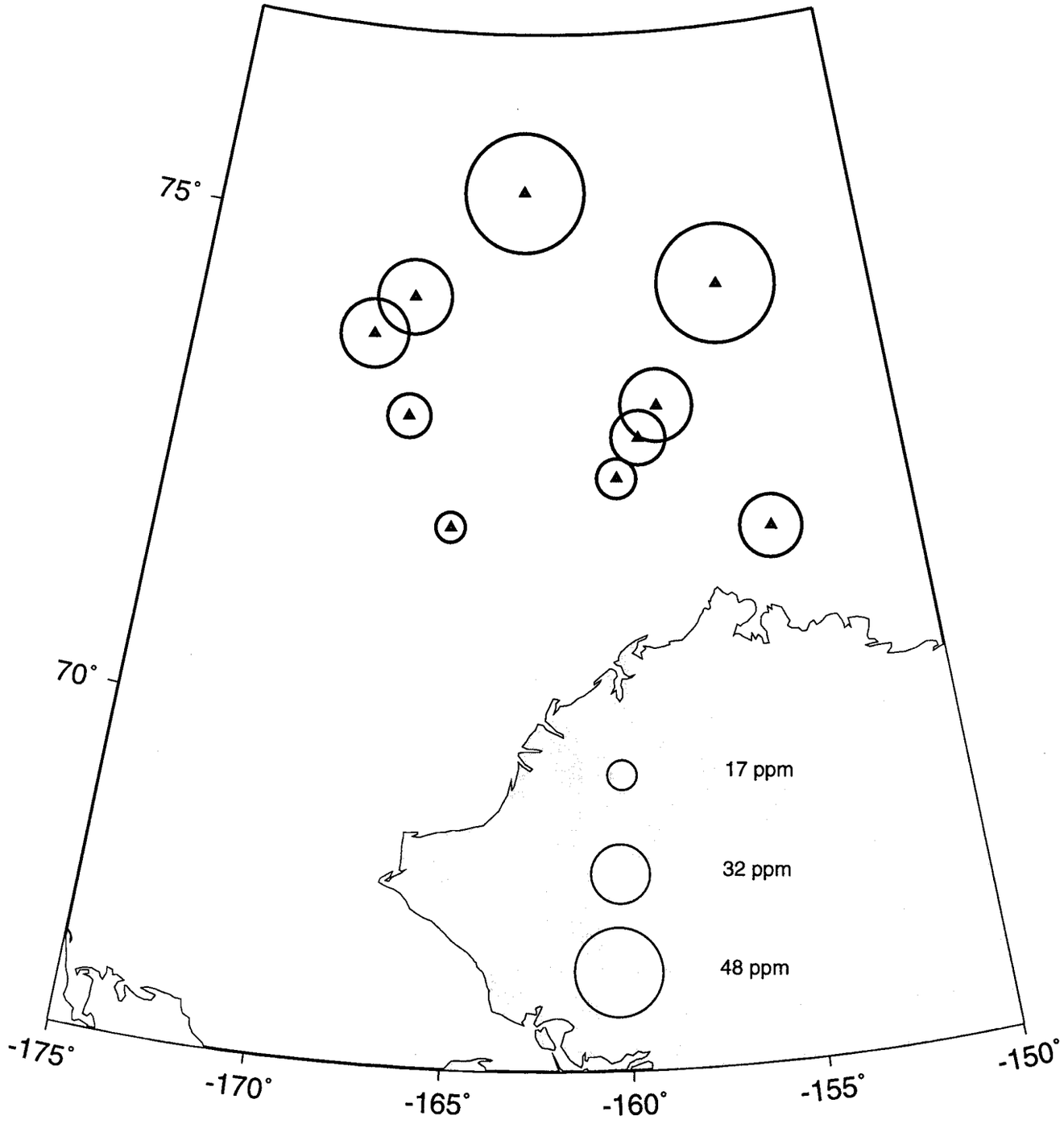
B10-Polar Star Sediments: Cadmium



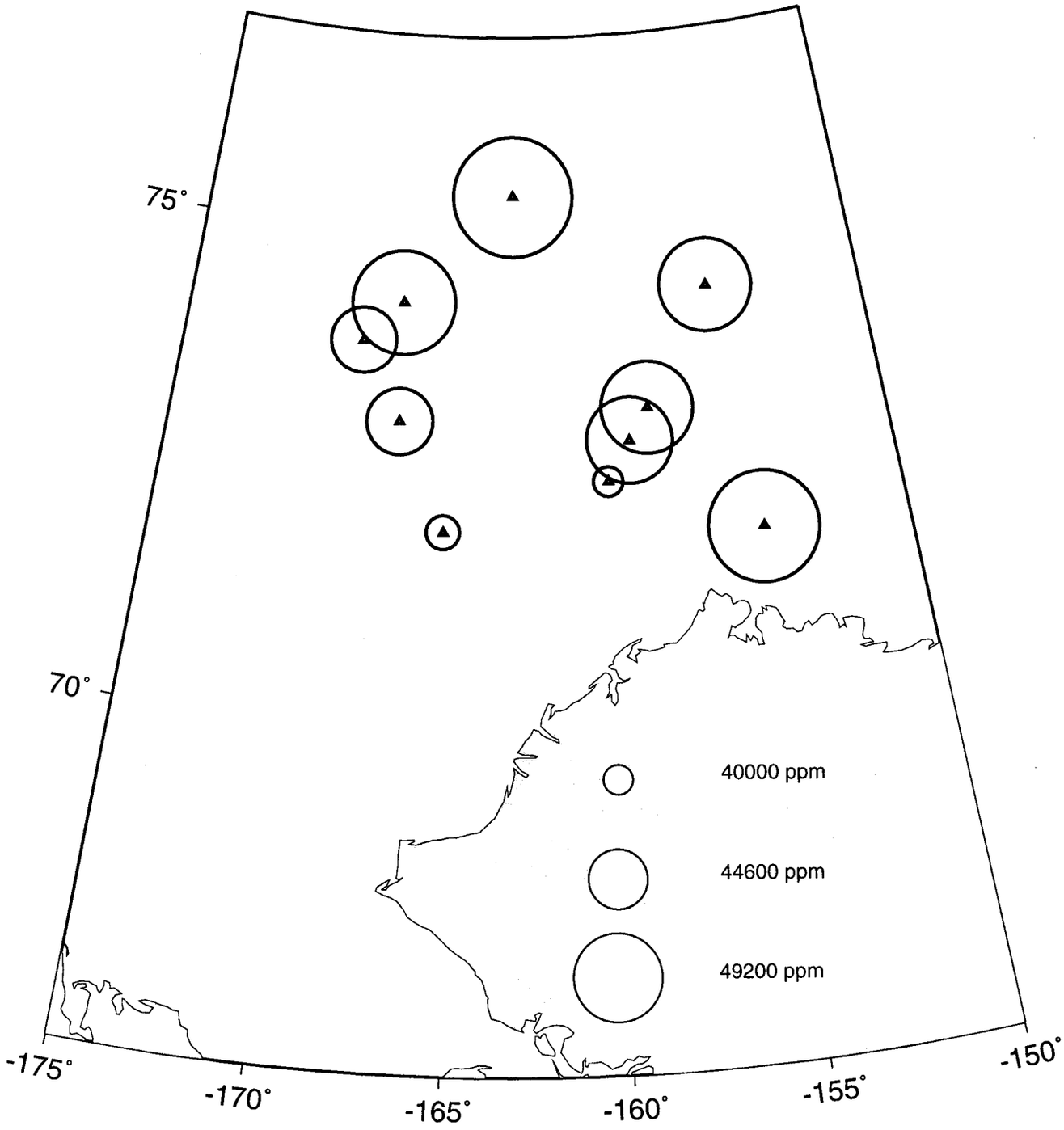
B11-Polar Star Sediments: Chromium



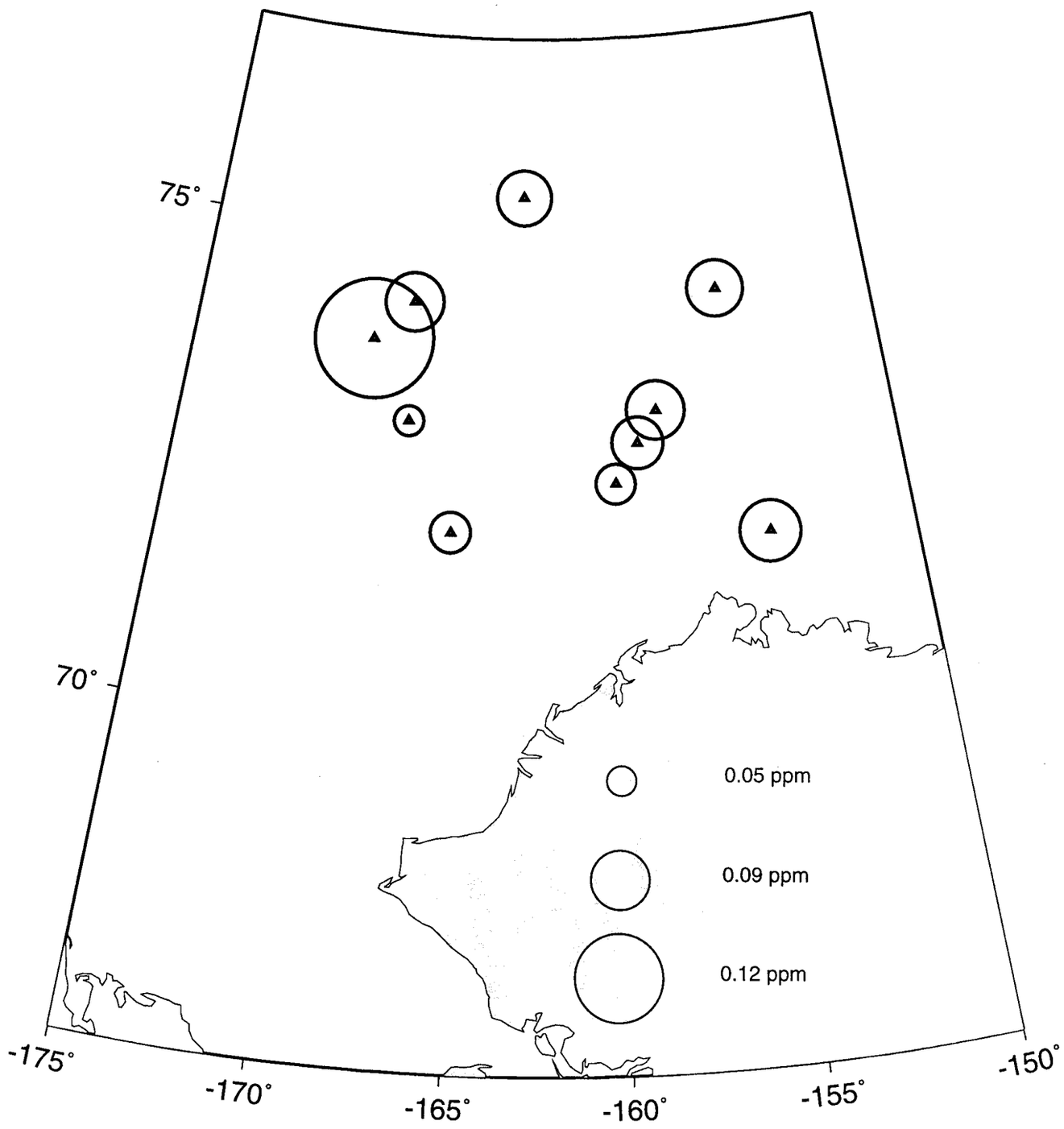
B12-Polar Star Sediments: Copper



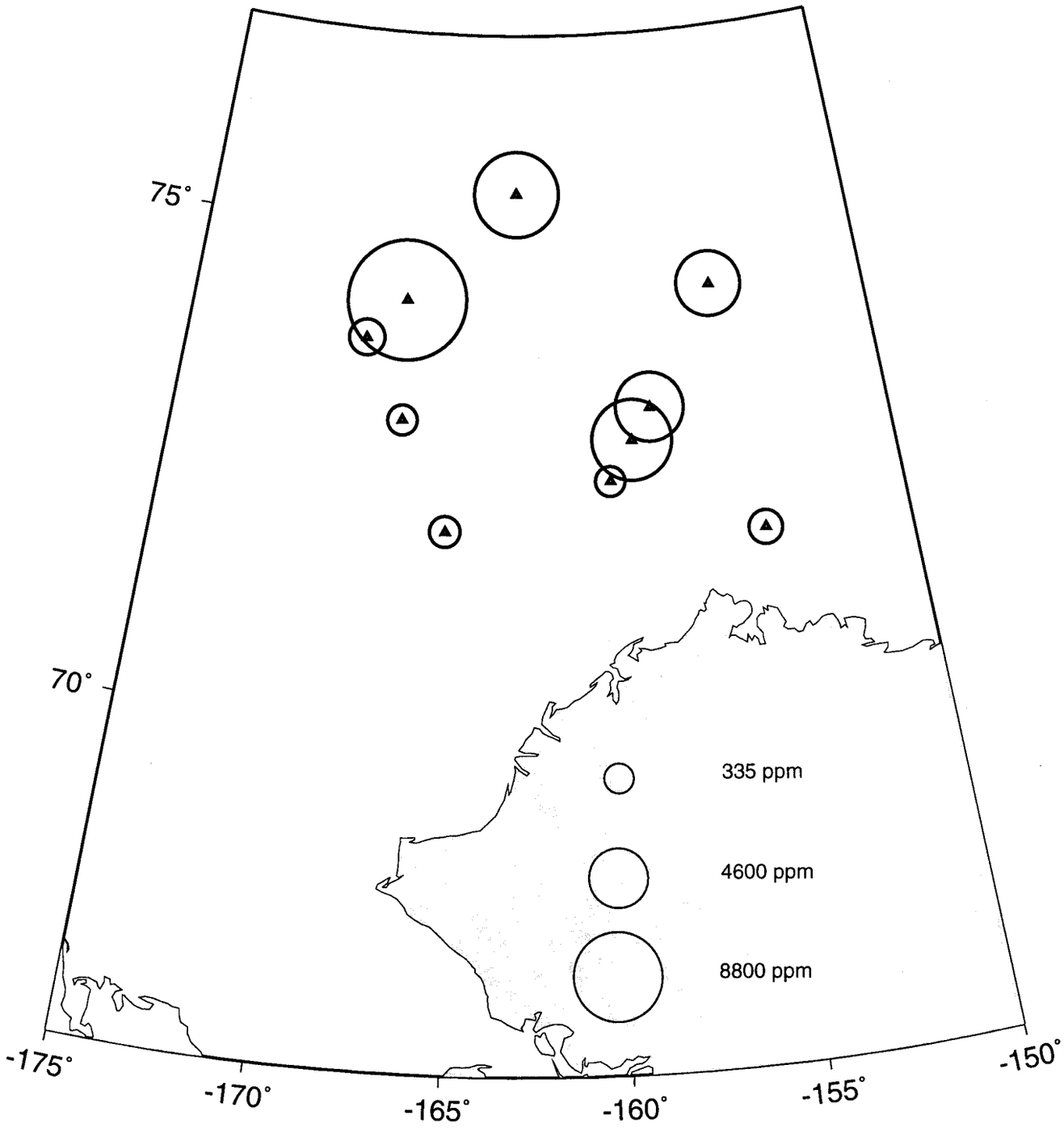
B13-Polar Star Sediments: Iron



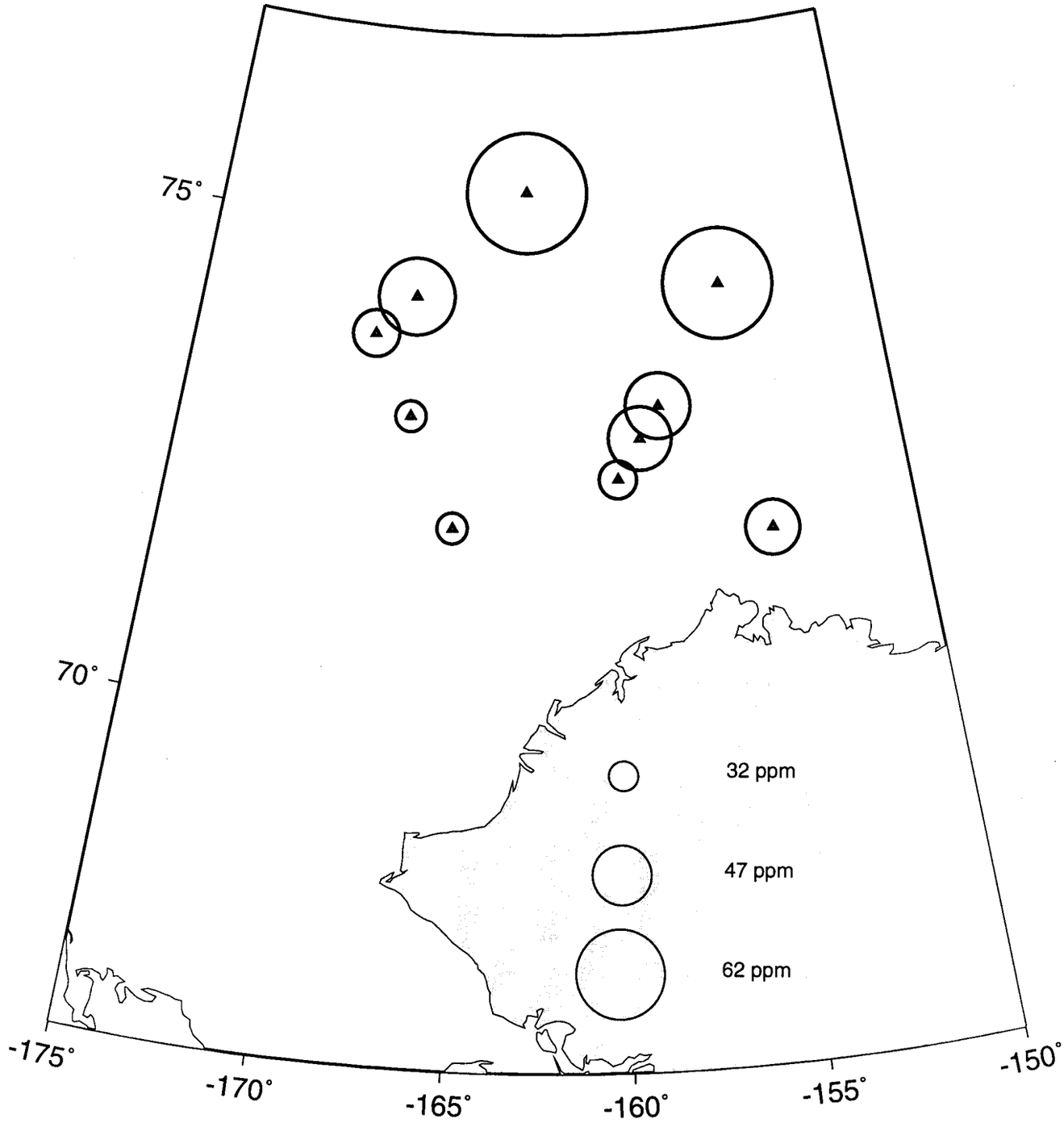
B14-Polar Star Sediments: Mercury



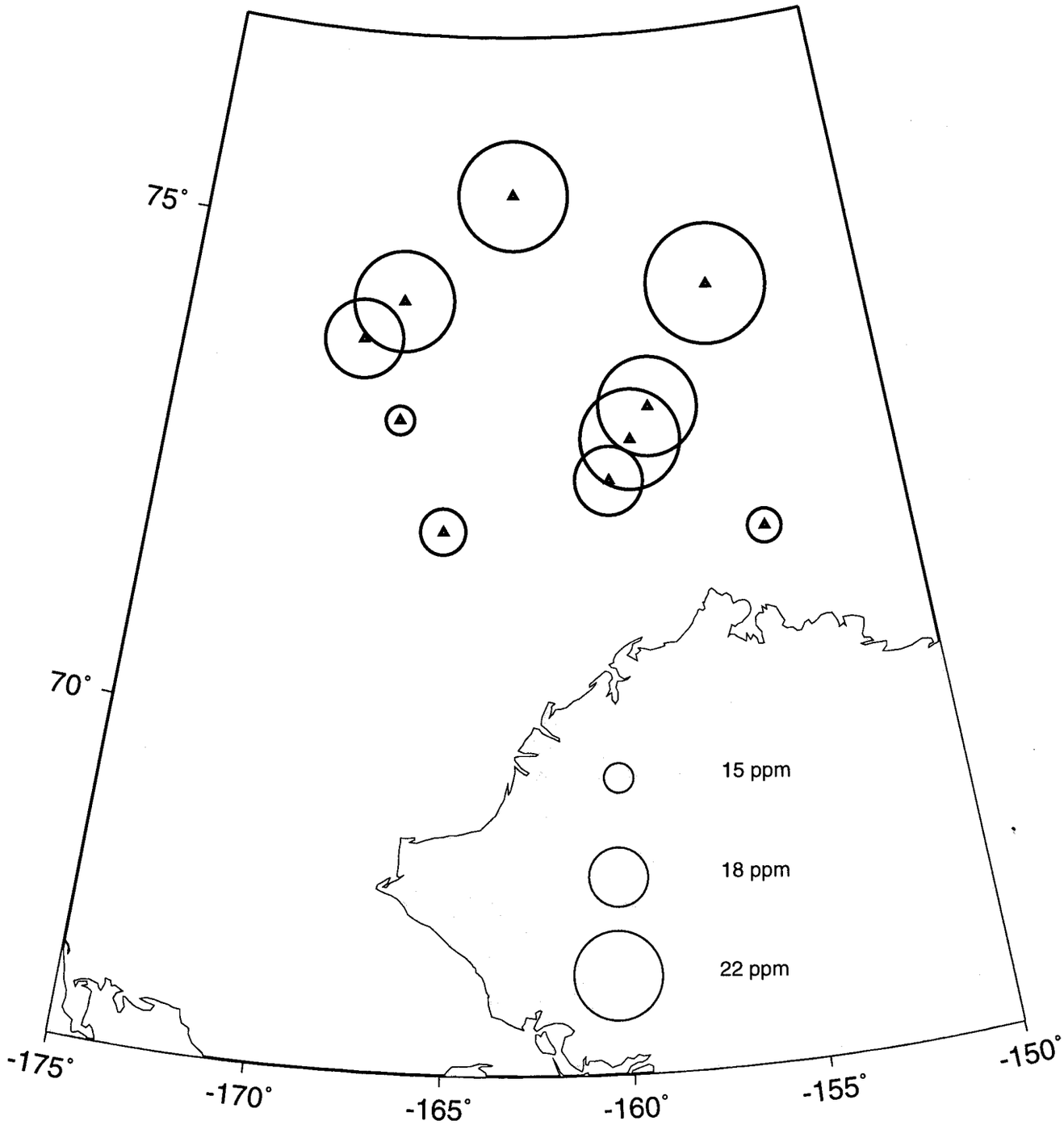
B15-Polar Star Sediments: Manganese



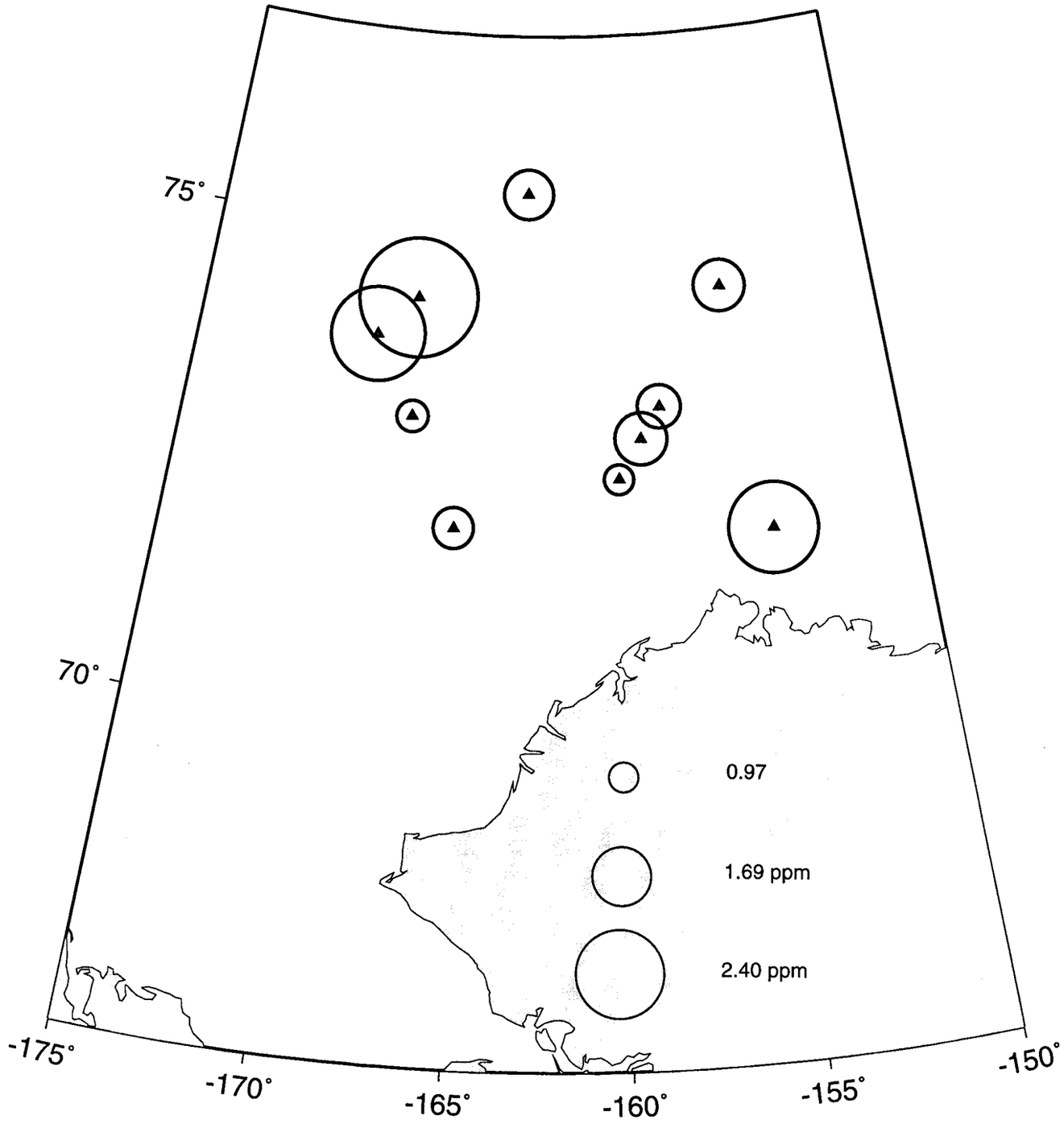
B16-Polar Star Sediments: Nickel



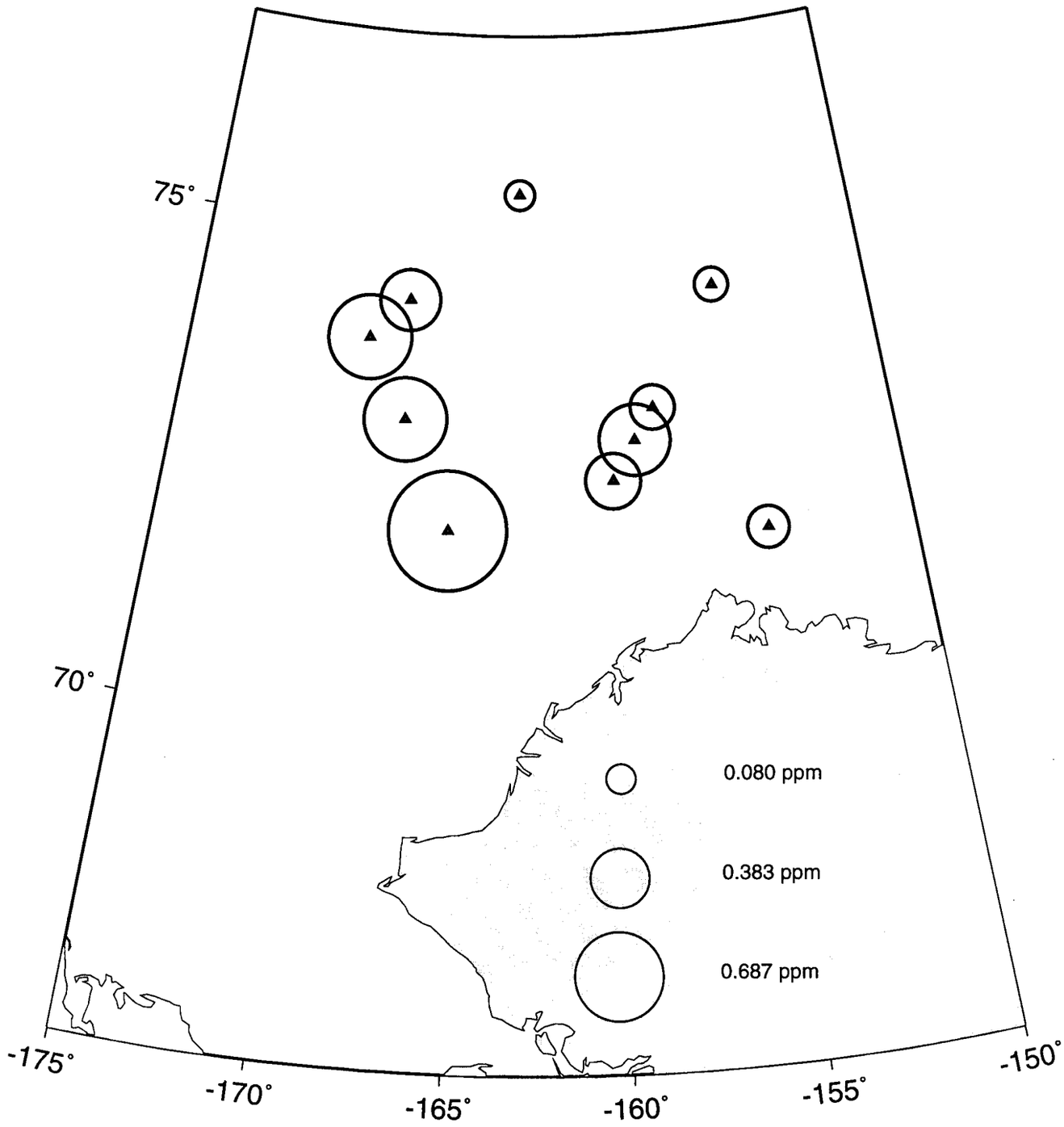
B17-Polar Star Sediments: Lead



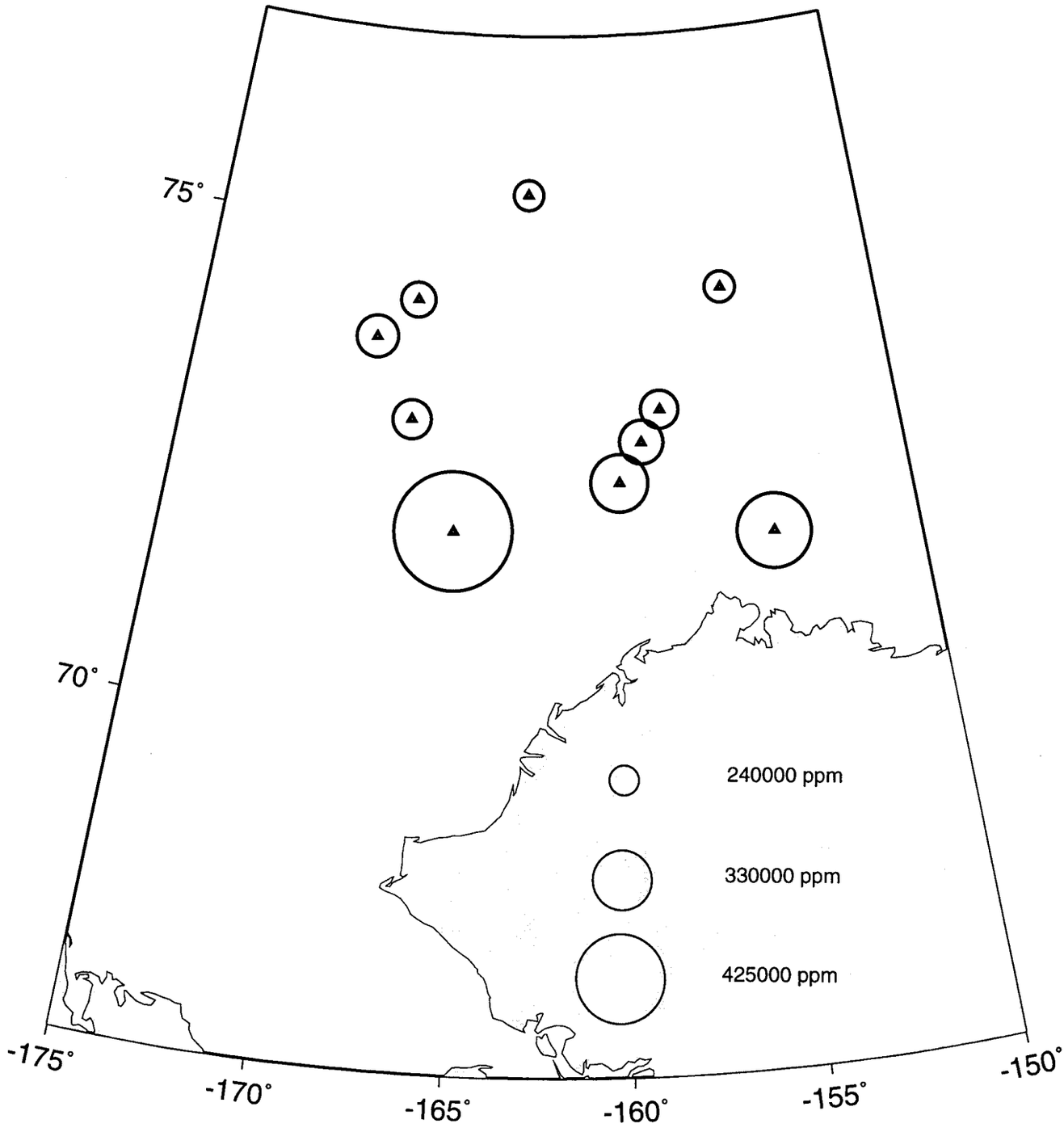
B18-Polar Star Sediments: Antimony



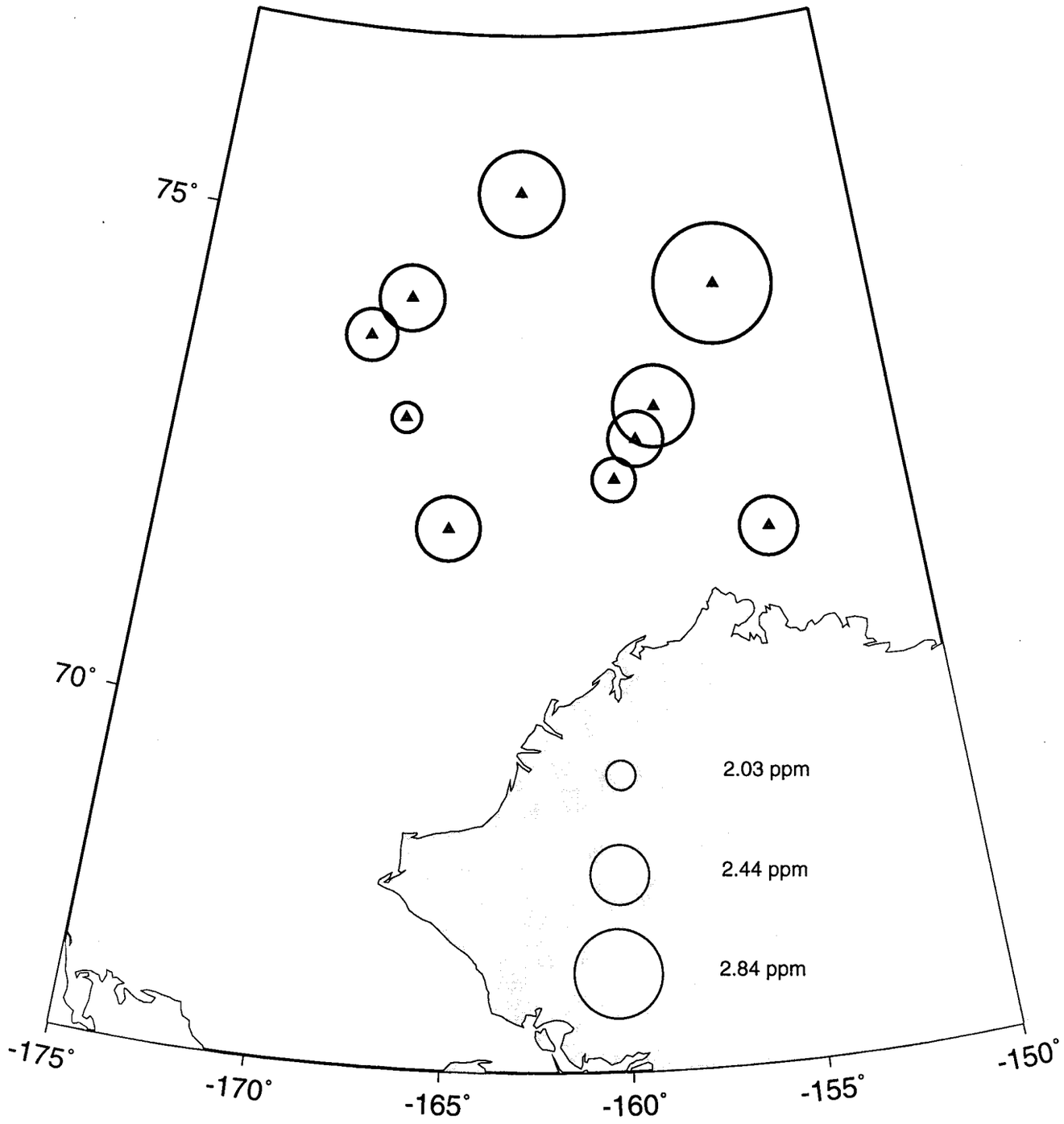
B19-Polar Star Sediments: Selenium



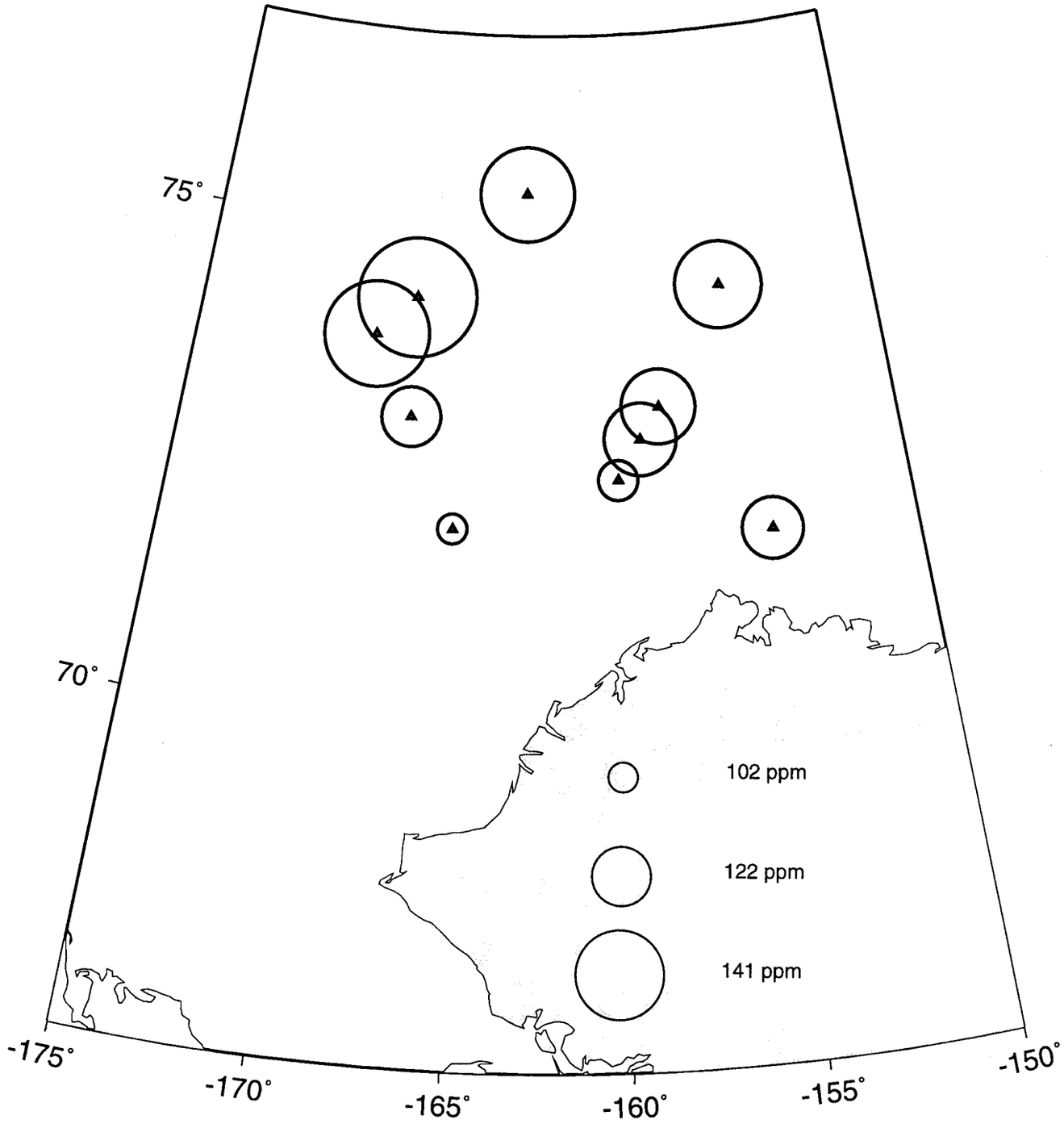
B20-Polar Star Sediments: Silicium



B21-Polar Star Sediments: Tin



B22-Polar Star Sediments: Zinc

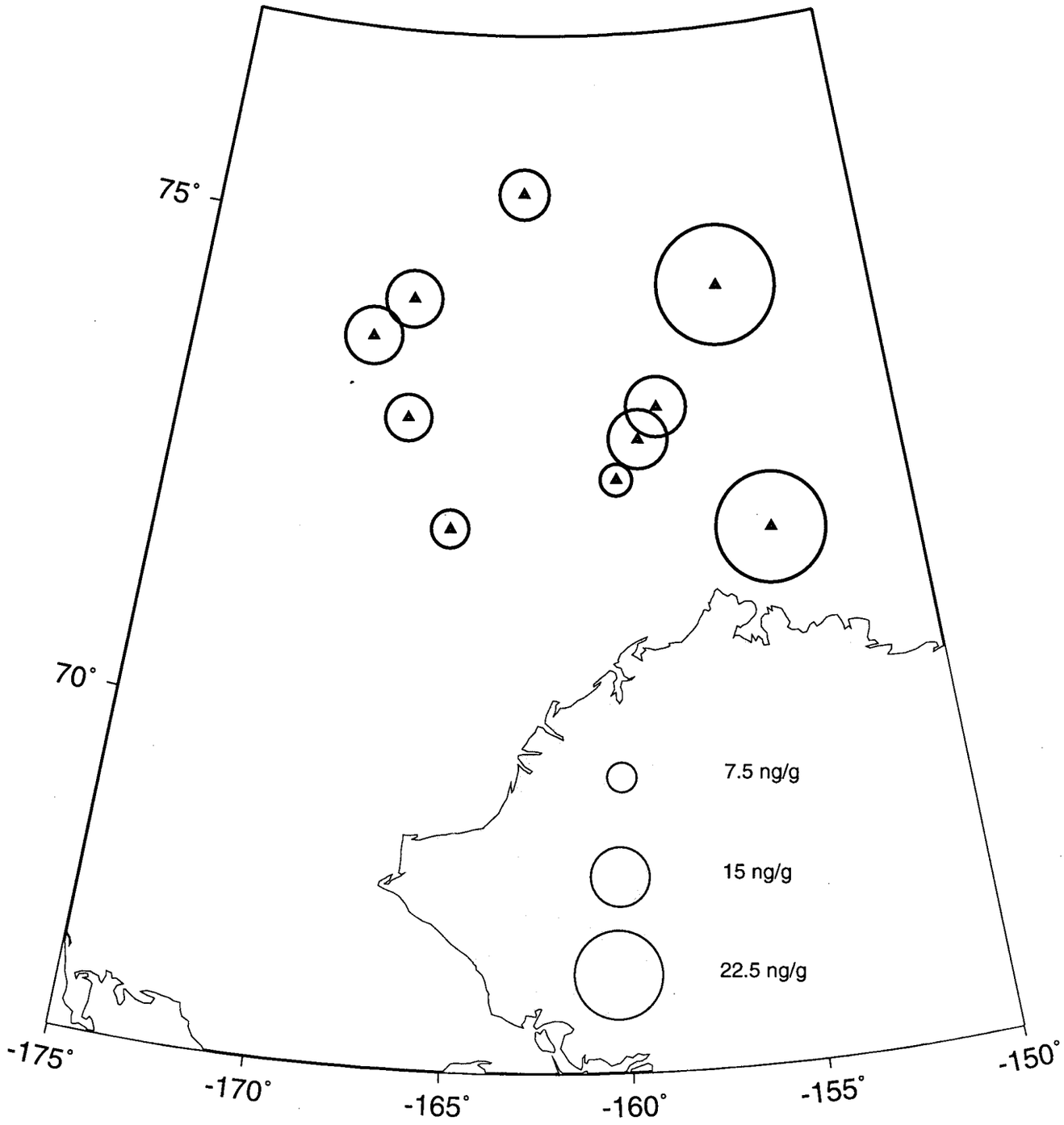


Organic compounds (Concentrations in ng/g dry weight)

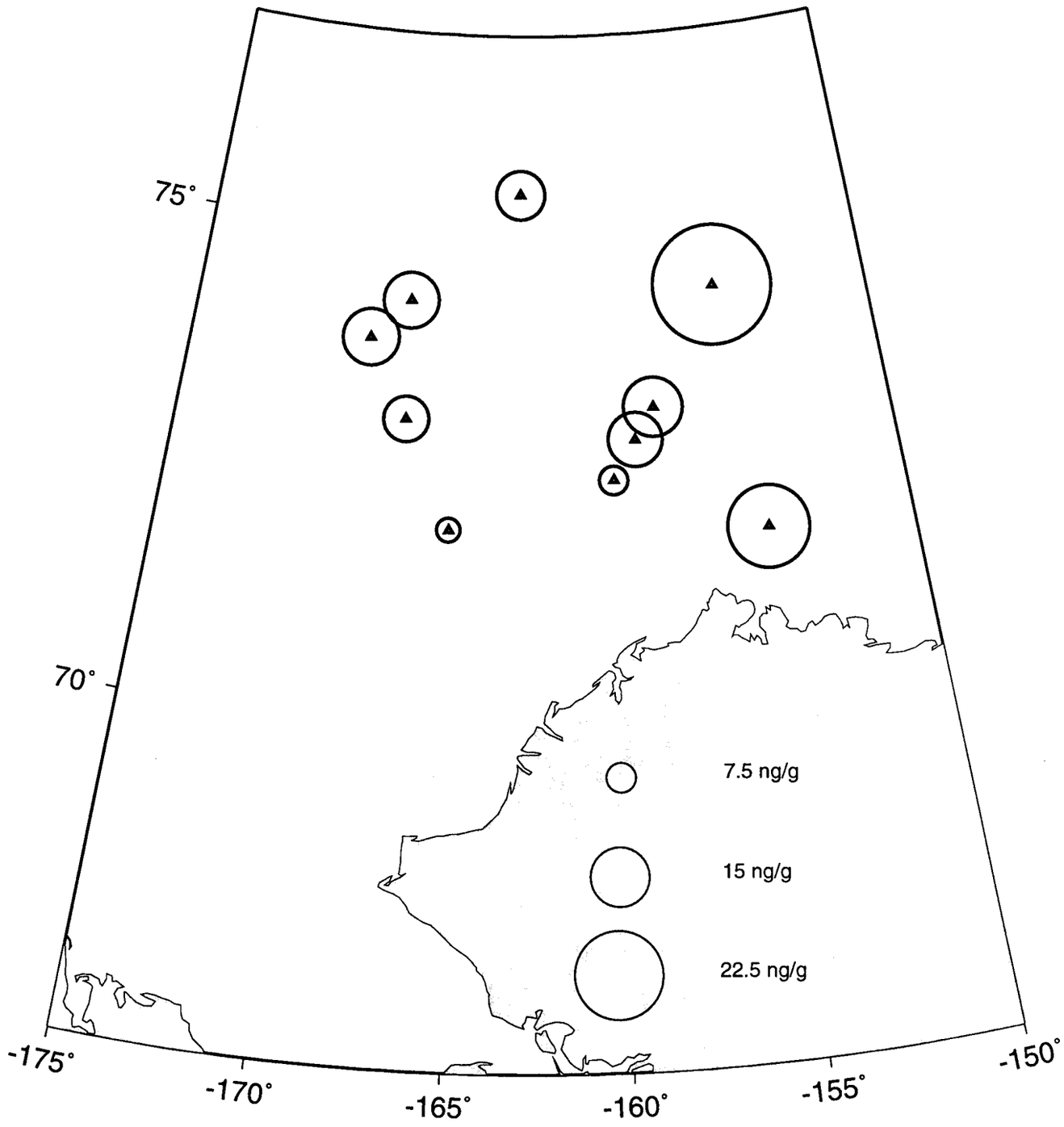
The data used to construct figures B23, B25, B27, B29, B31, B33, B35, B37, B39 are concentrations corrected for grain size variability.
All the other figures used raw values, uncorrected for grain size variability.

In figure B28, Phenant/Anthra (Uncorr.): Phenanthrenes and anthracenes uncorrected for grain size variability.

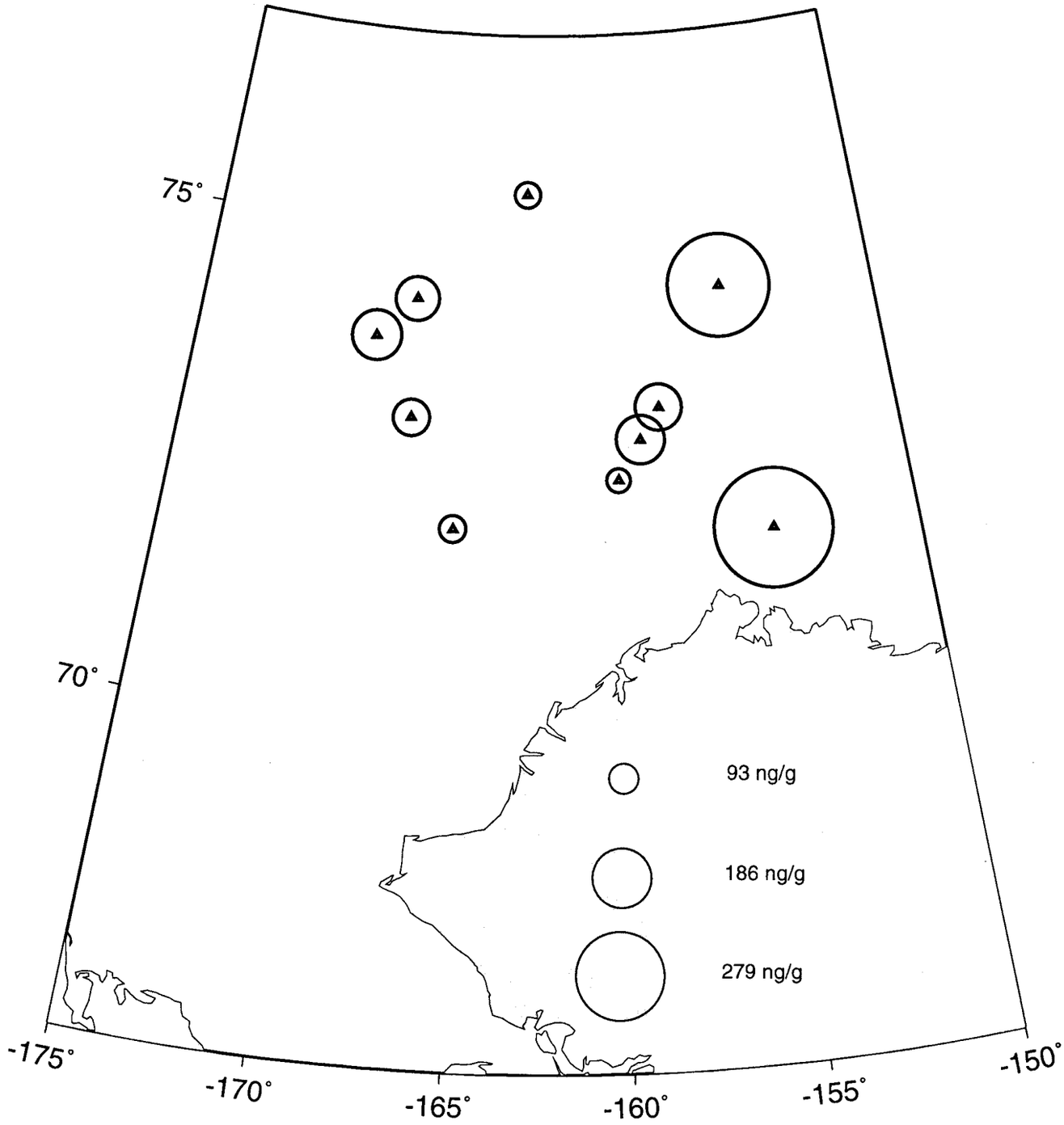
B23-Polar Star Sediments: Naphtalene



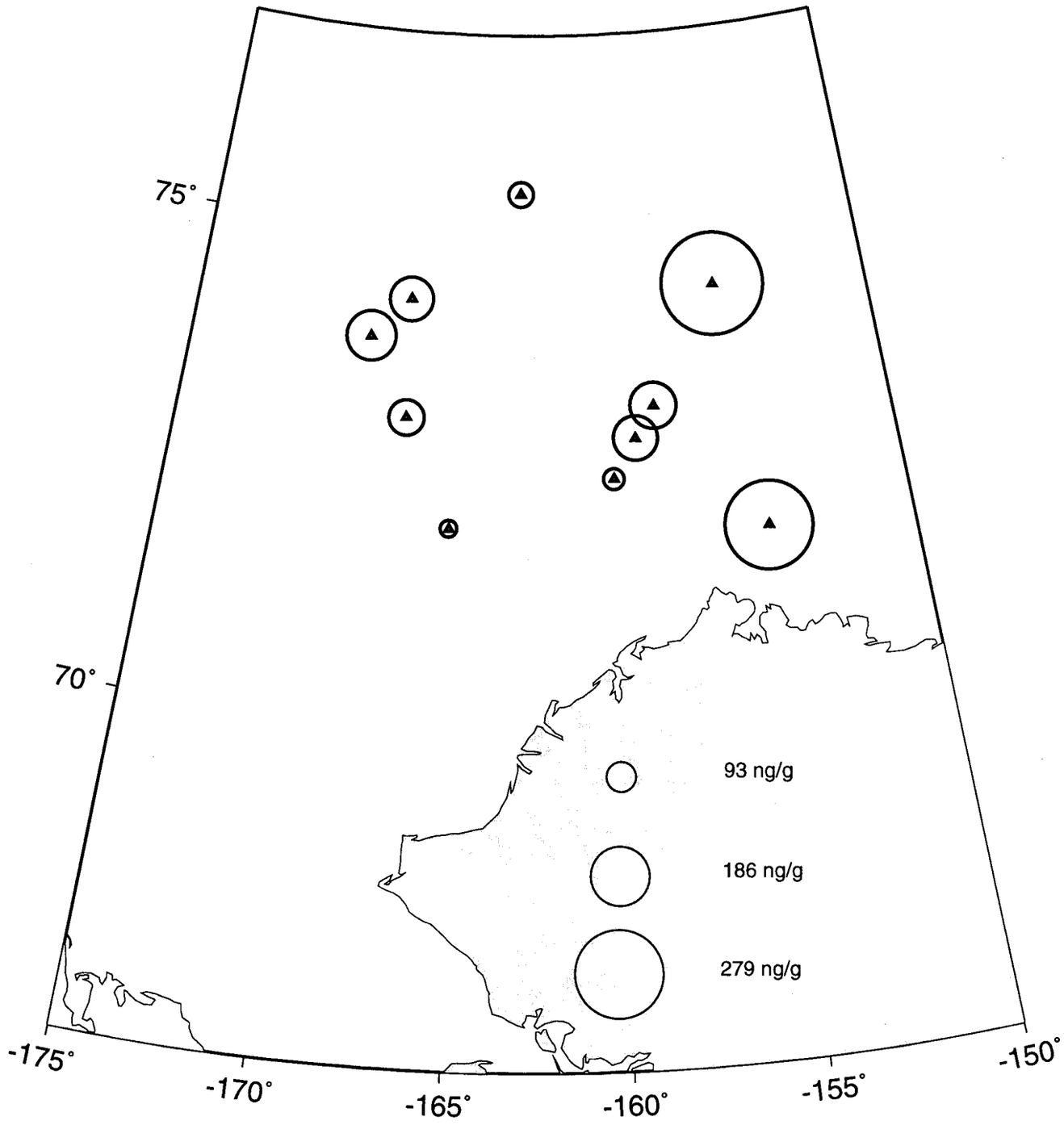
B24-Polar Star Sediments: Naphtalene (uncorrected)



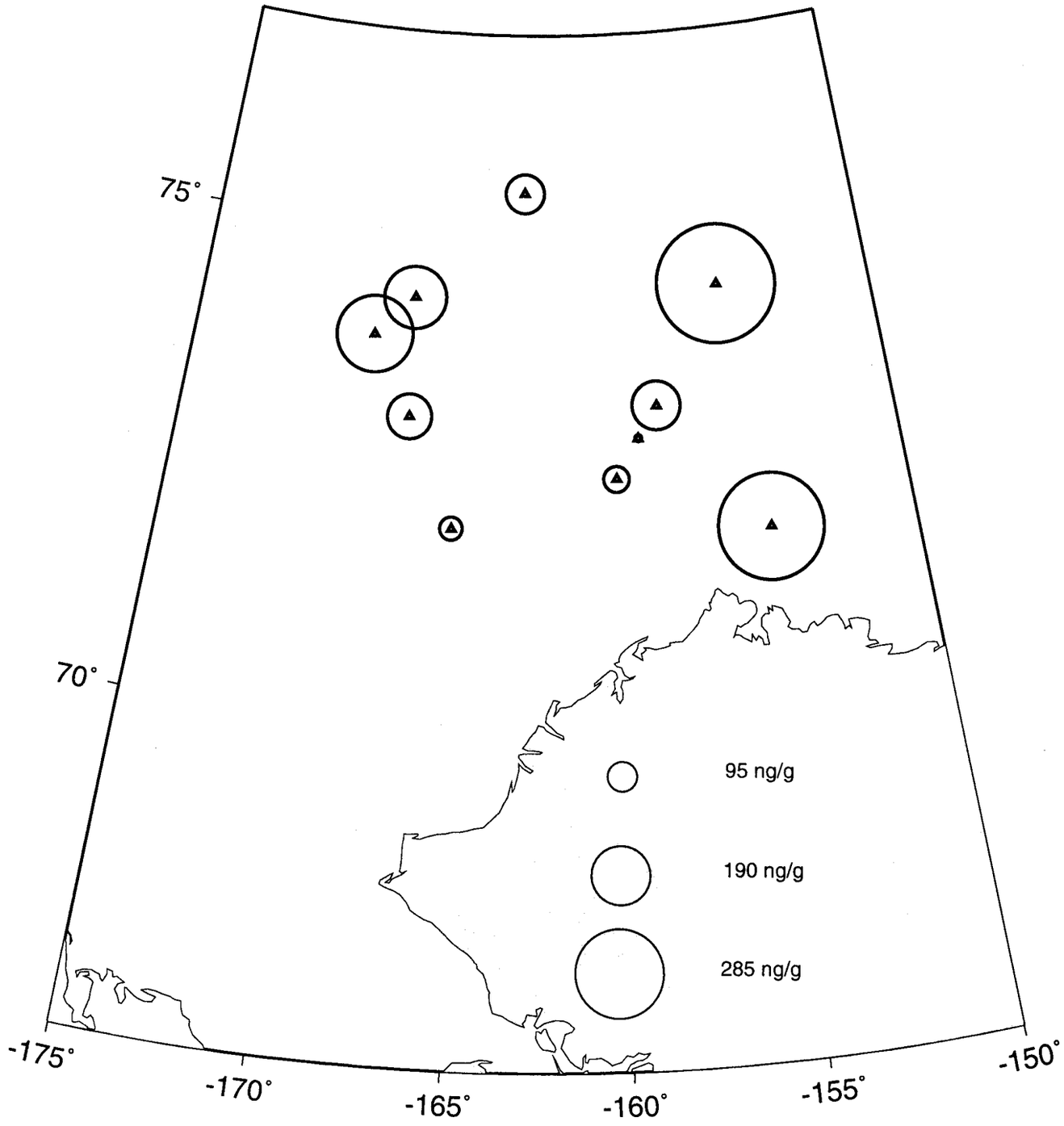
B25-Polar Star Sediments: Total Naphtalenes



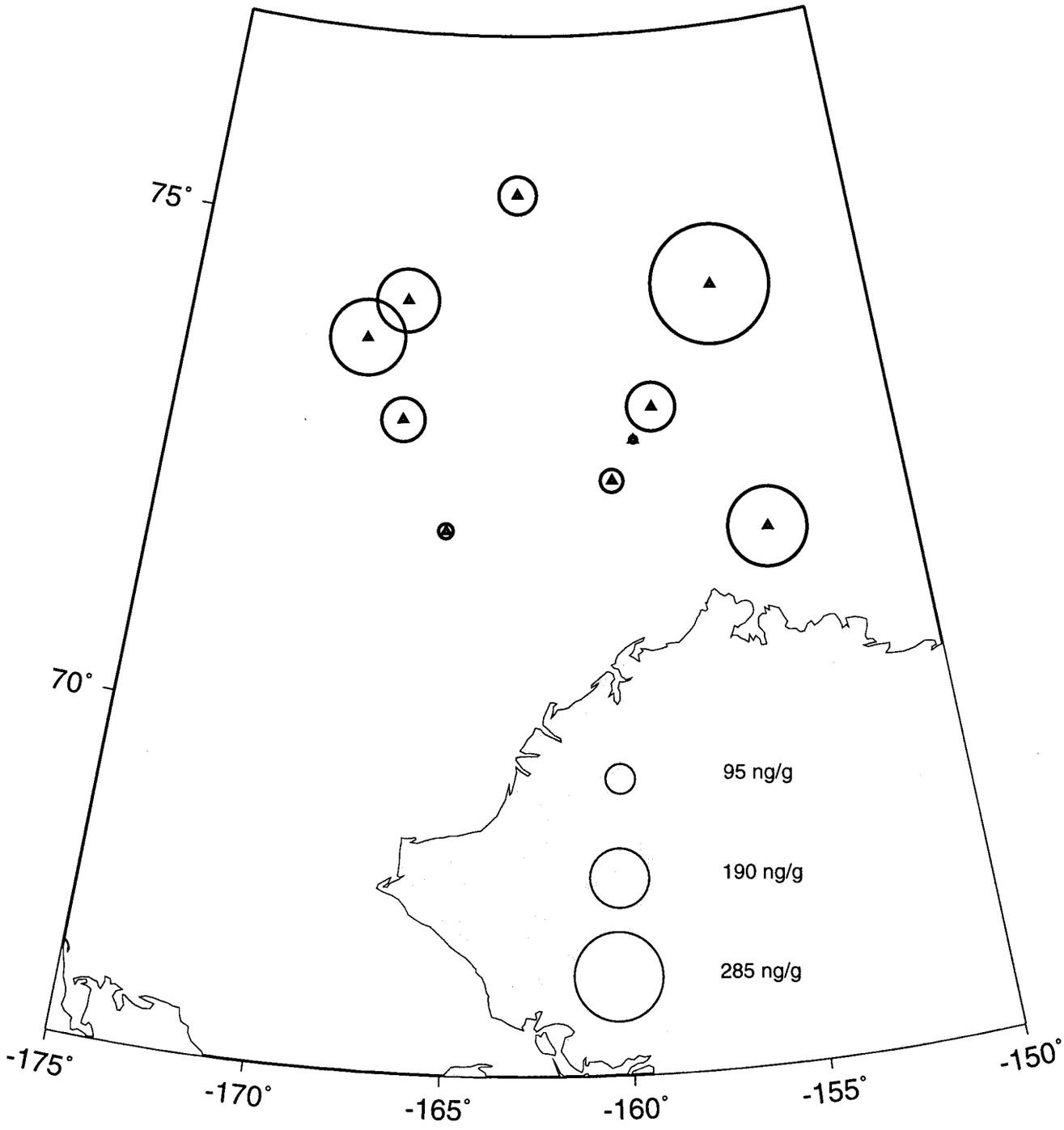
B26-Polar Star Sediments: Total Naphtalenes (uncorrected)



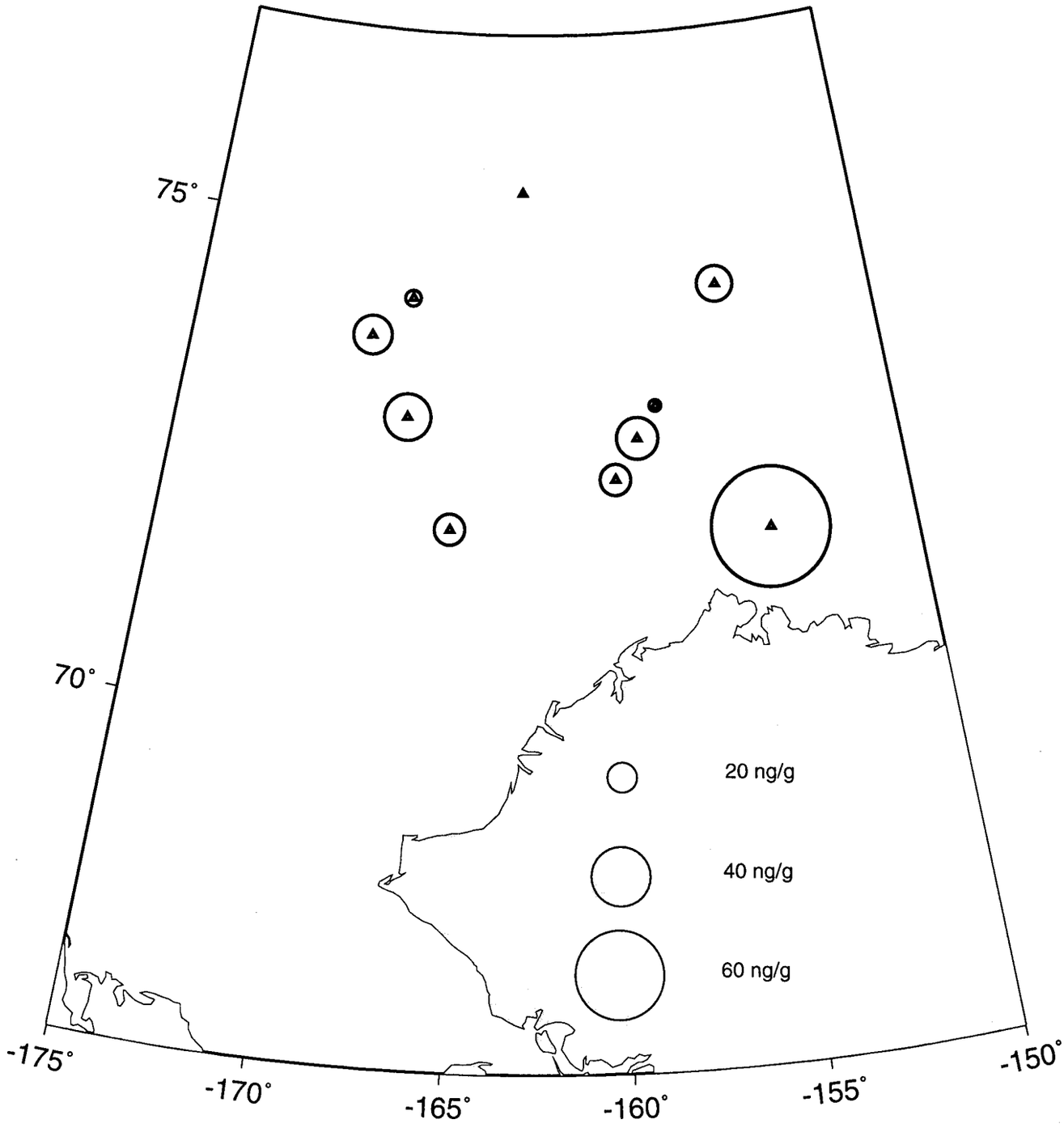
B27-Polar Star Sediments: Phenanthrenes/Anthracenes



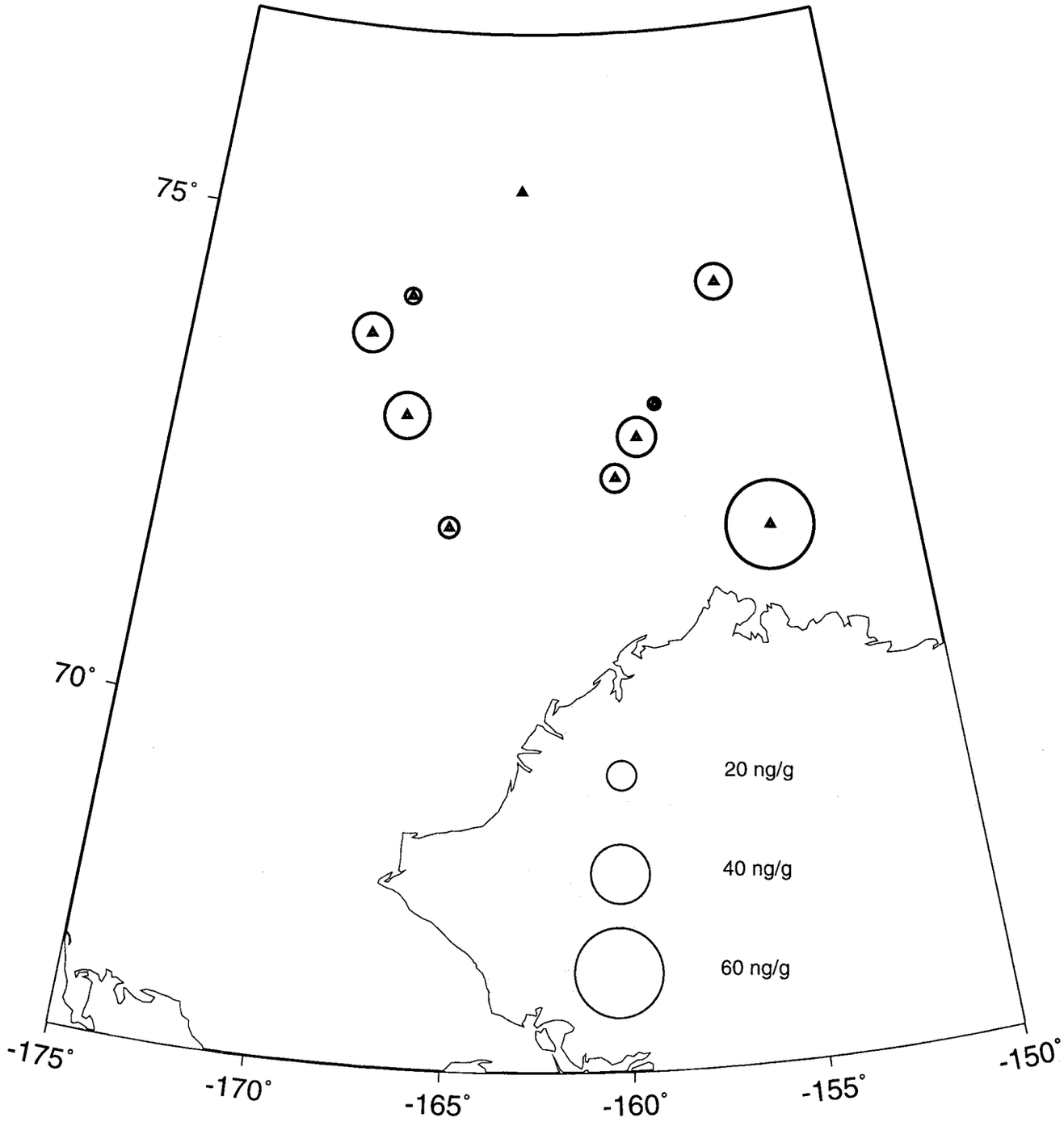
B28-Polar Star Sediments: Phenant/Anthra (uncorr.)



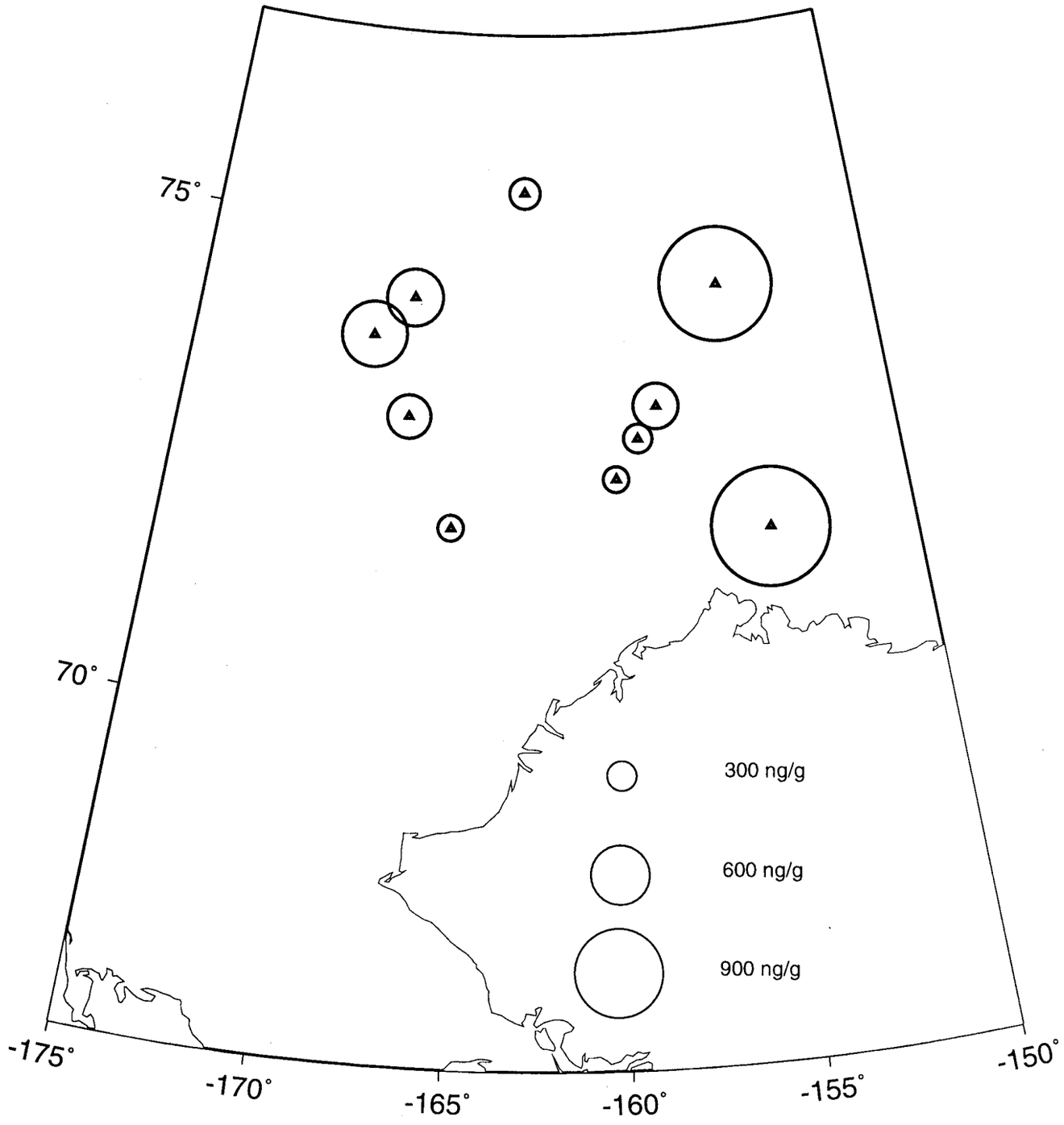
B29-Polar Star Sediments: Perylene



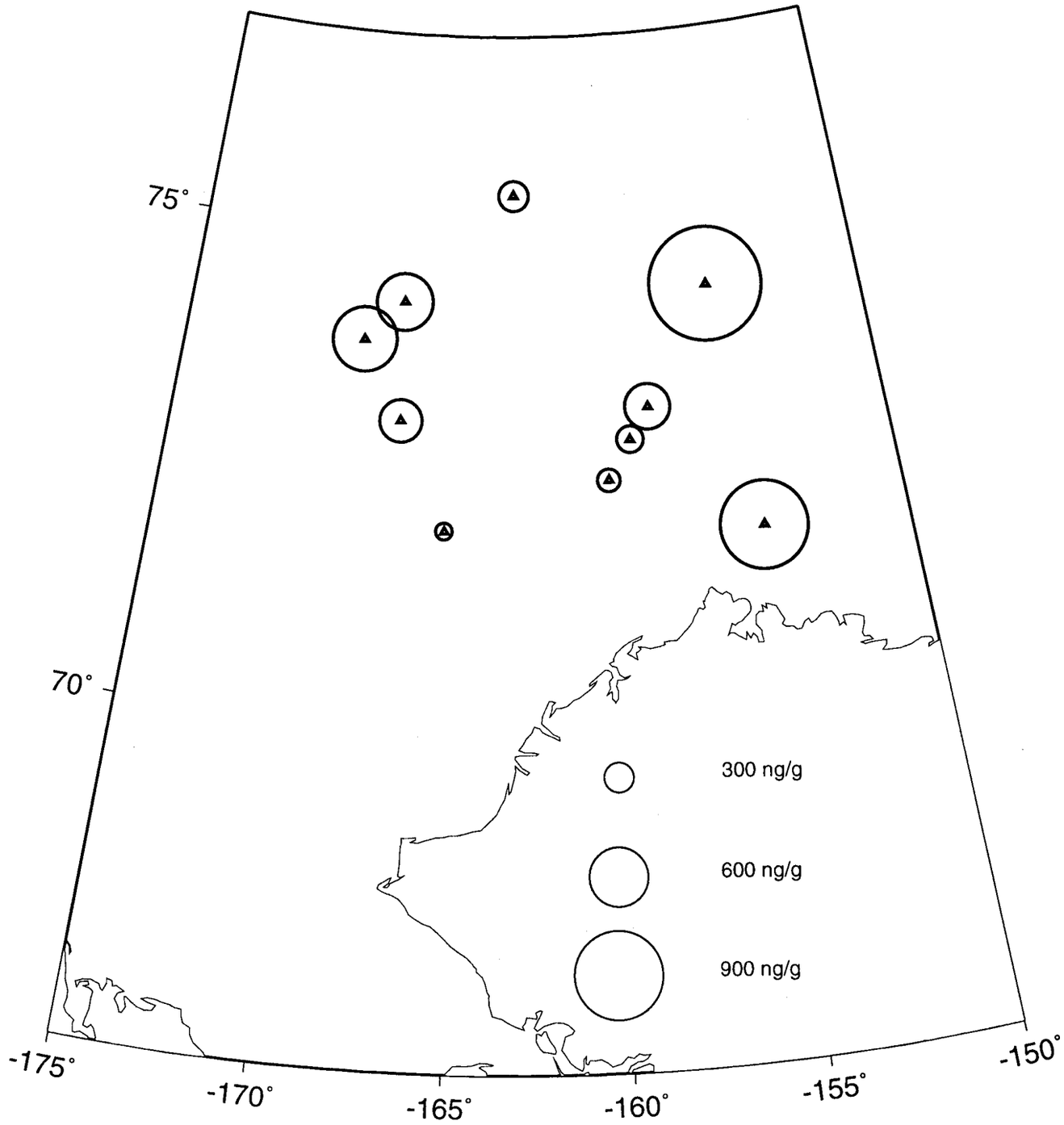
B30-Polar Star Sediments: Perylene (uncorrected)



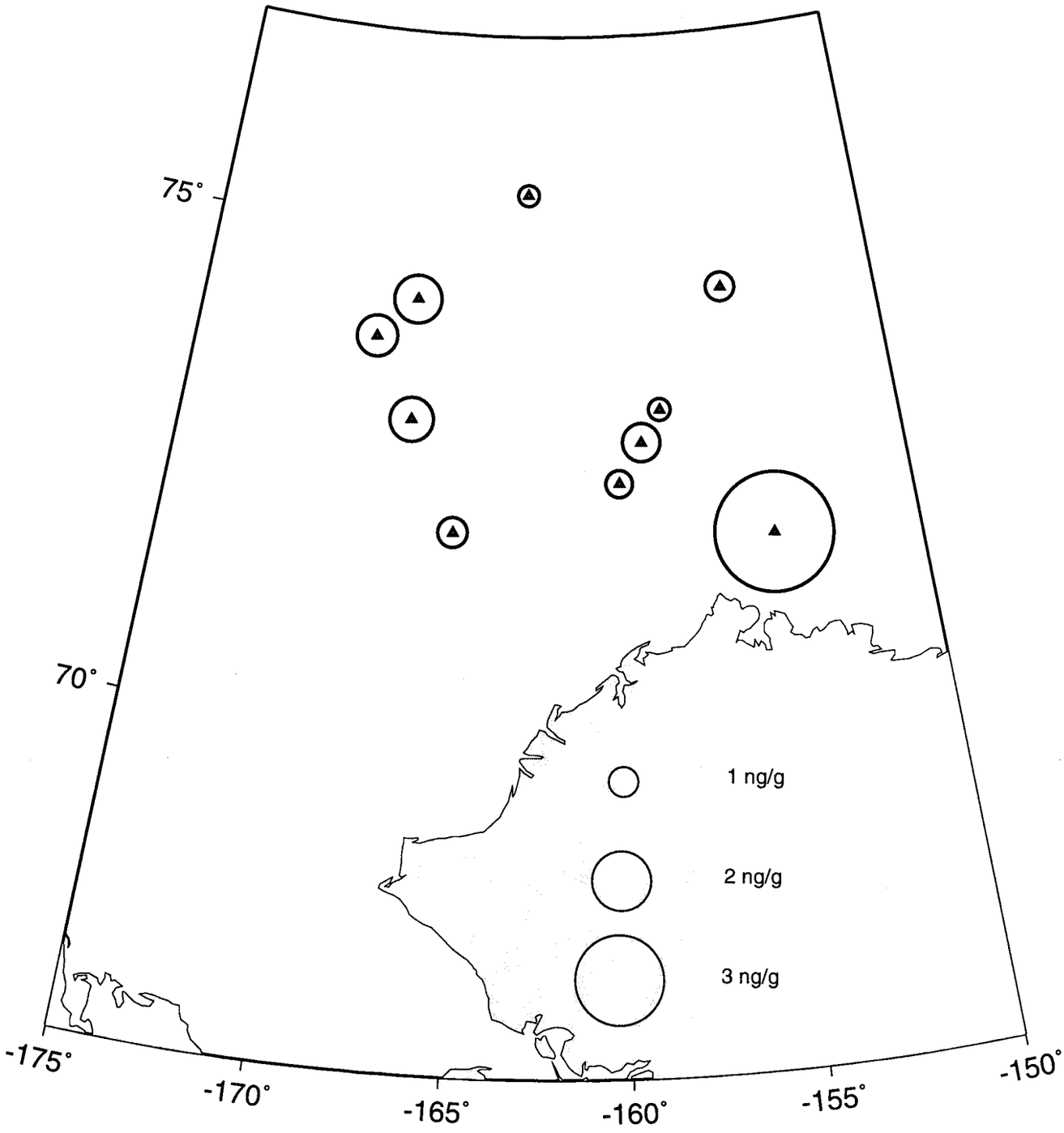
B31-Polar Star Sediments: Total PAHs



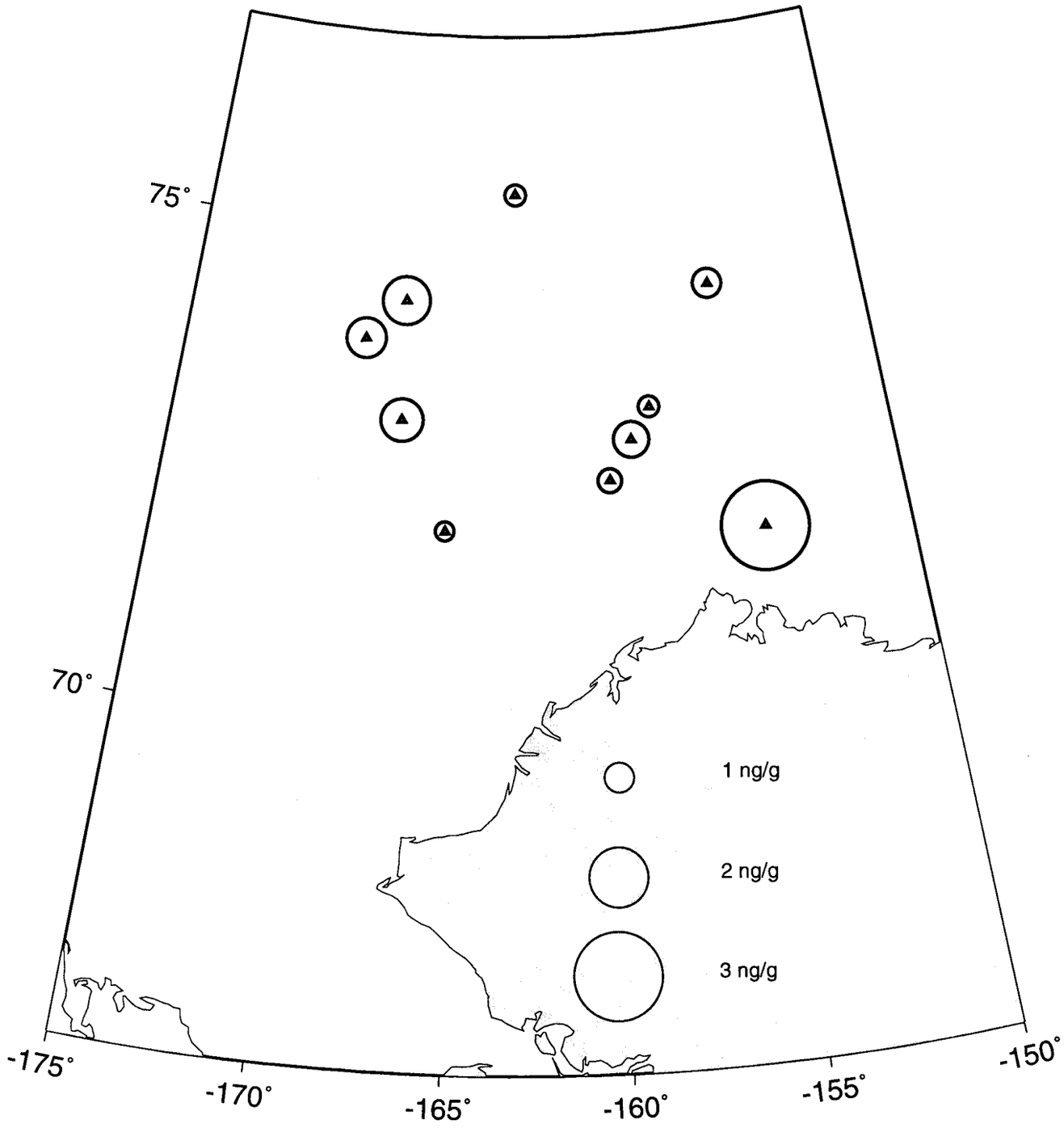
B32-Polar Star Sediments: Total PAHs (uncorrected)



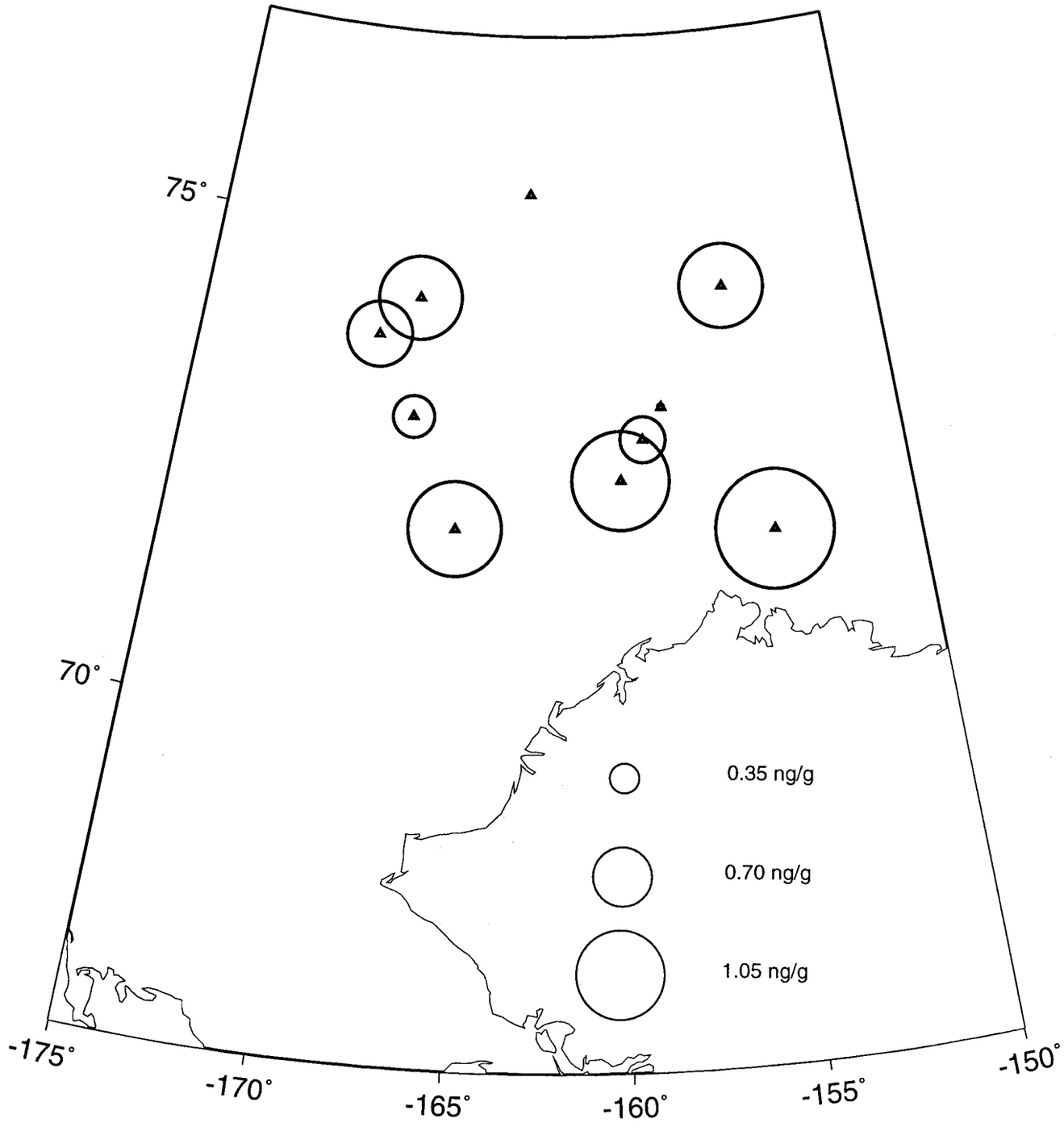
B33-Polar Star Sediments: Total PCBs



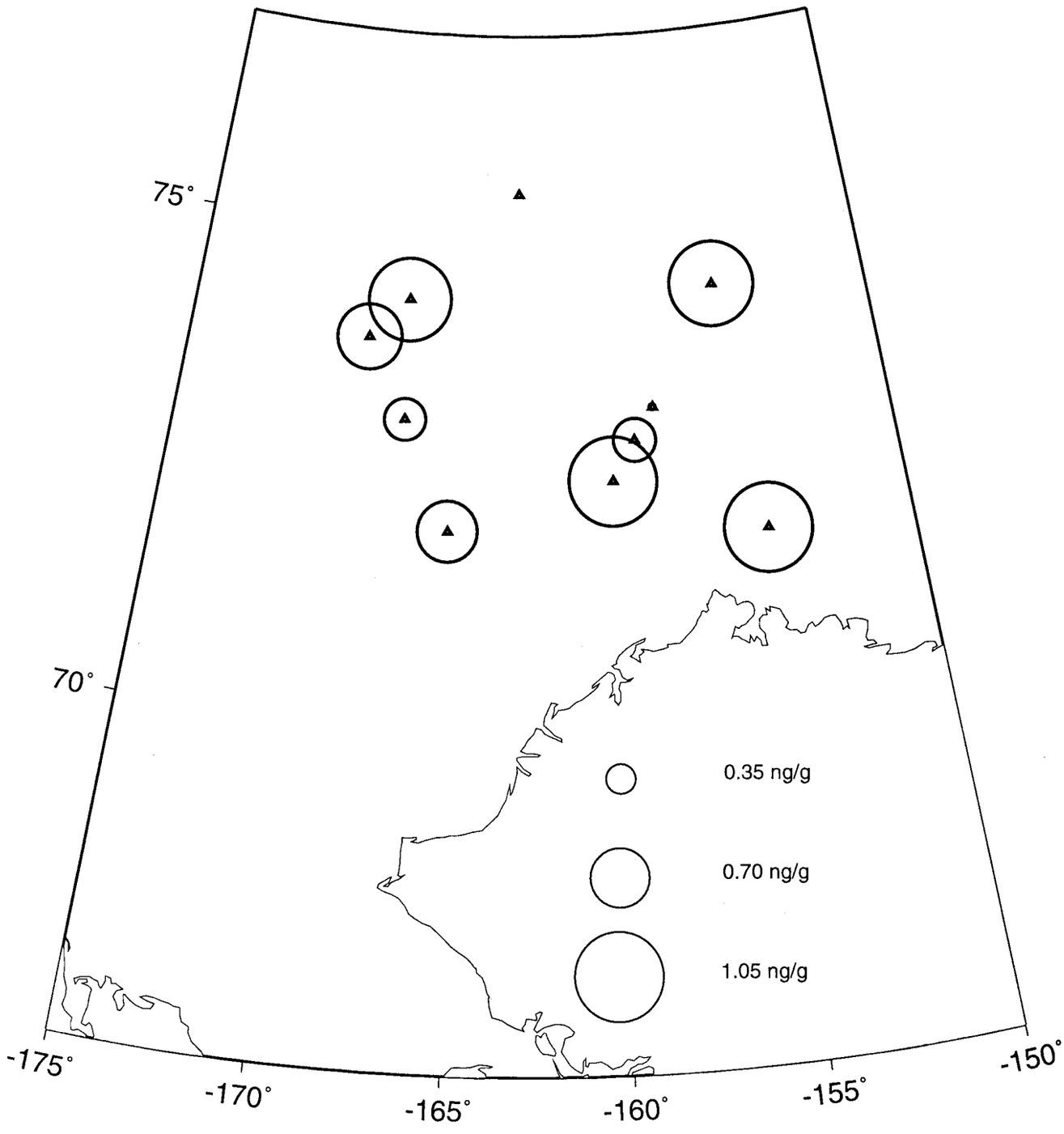
B34-Polar Star Sediments: Total PCBs (uncorrected)



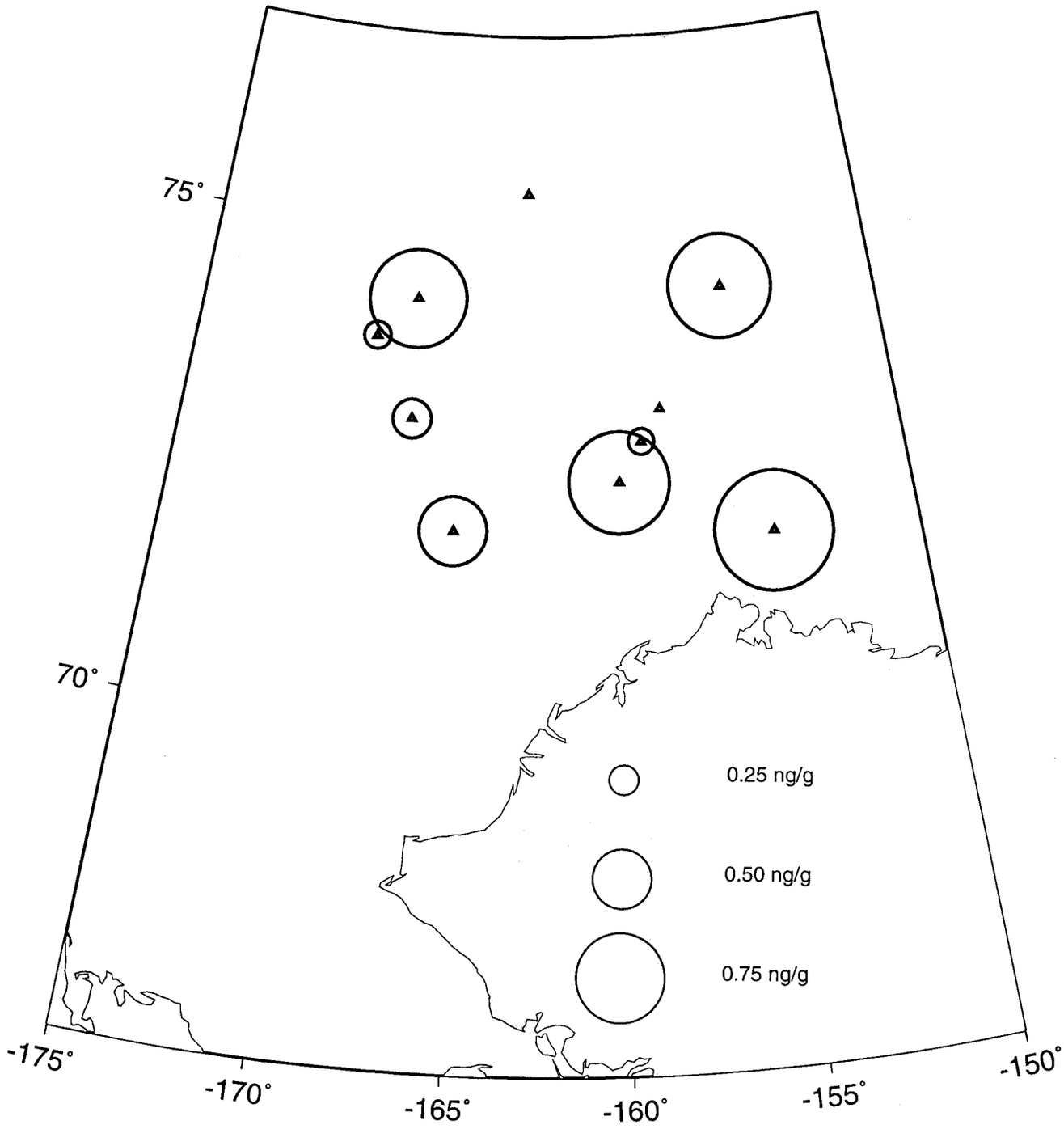
B35-Polar Star Sediments: Total Pesticides



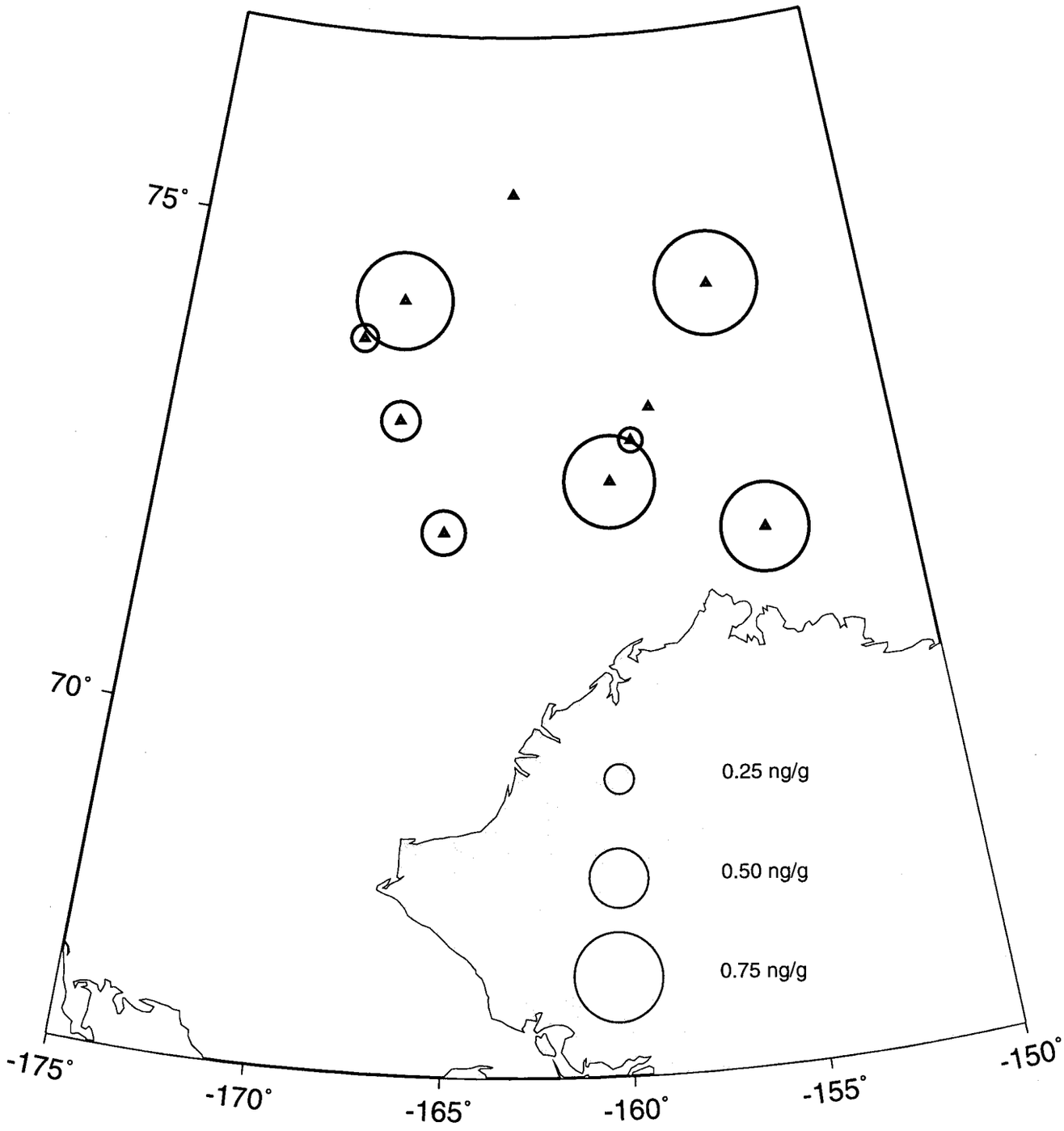
B36-Polar Star Sediments: Total Pesticides (uncorrected)



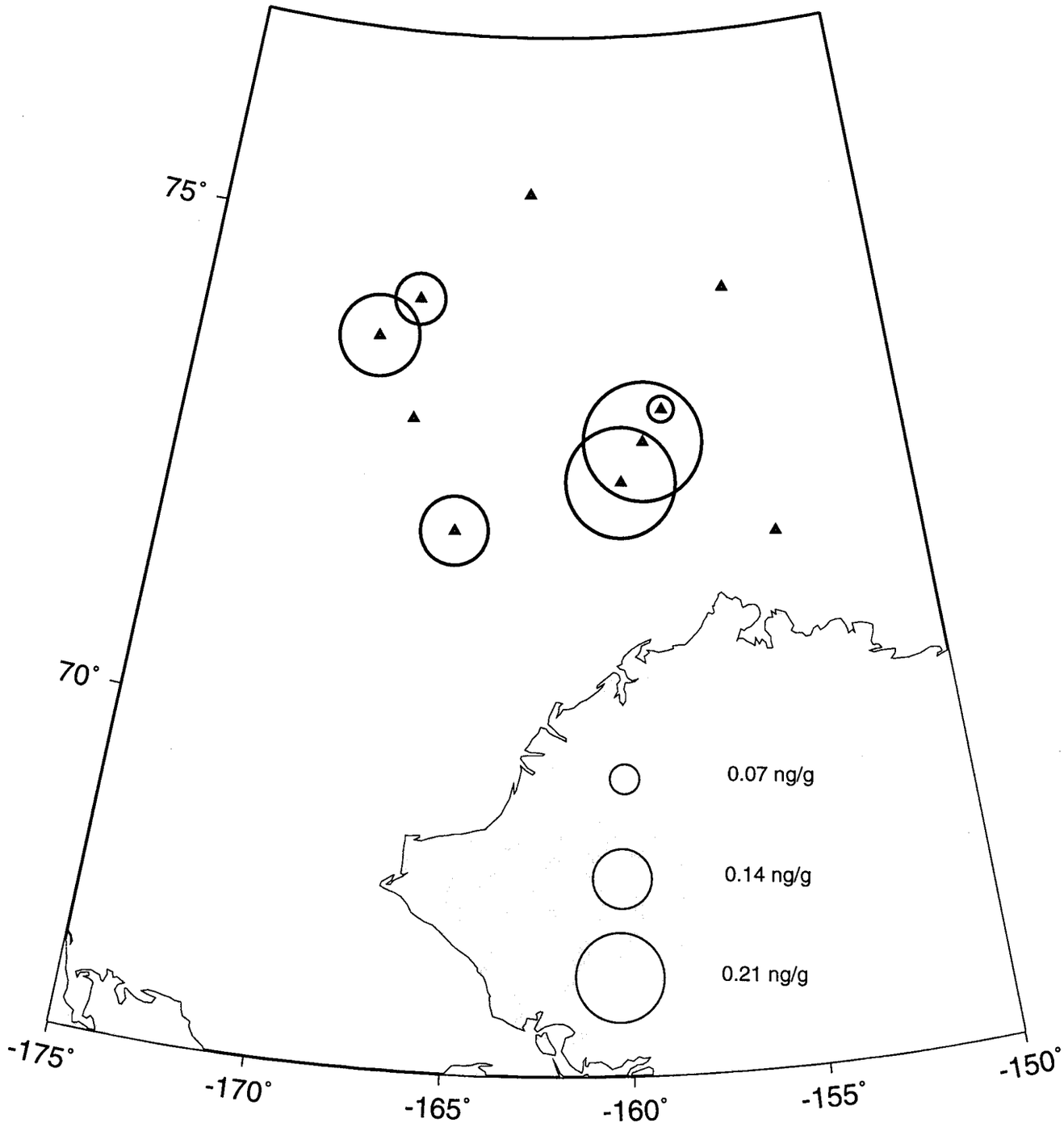
B37-Polar Star Sediments: Total DDTs



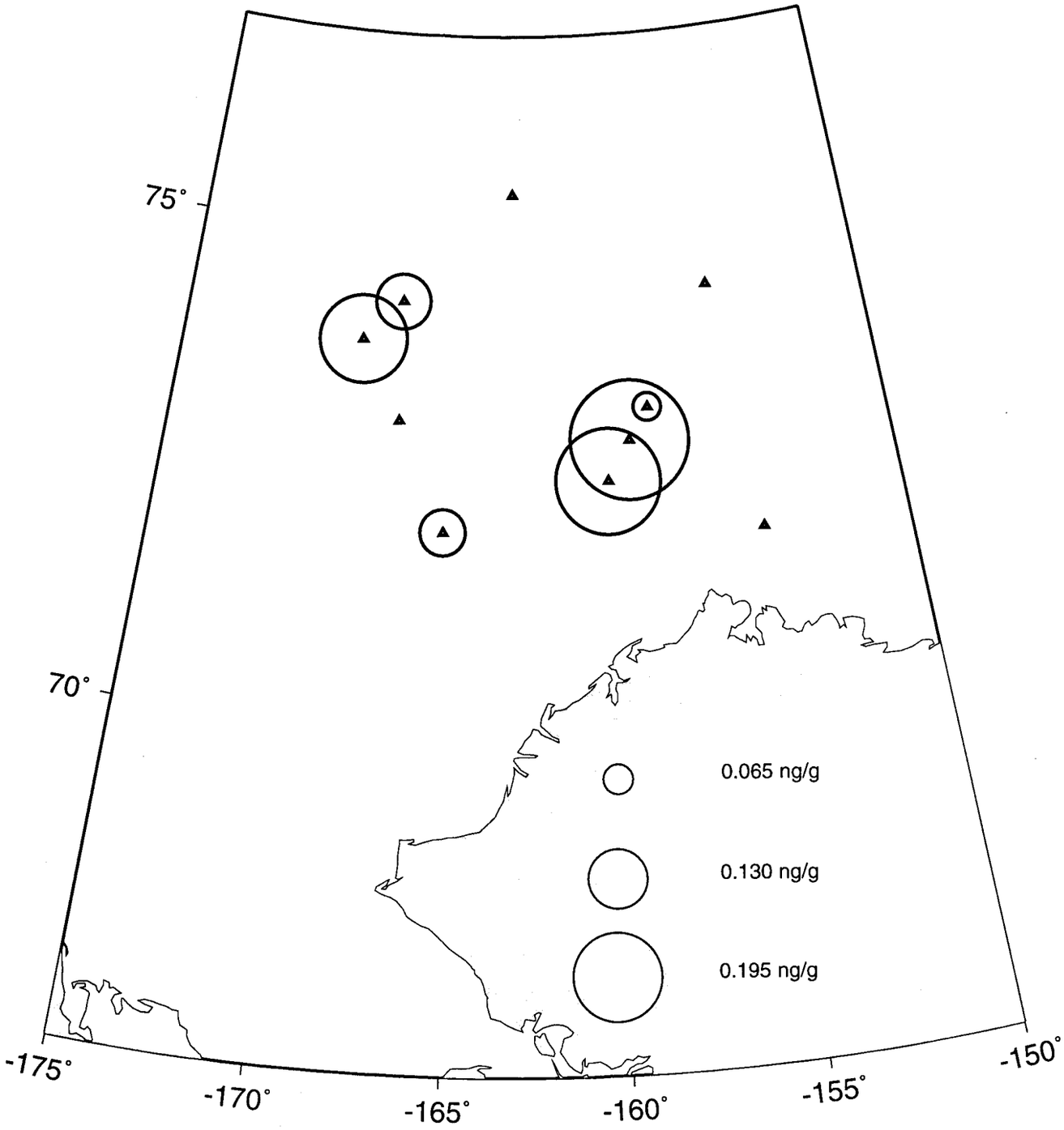
B38-Polar Star Sediments: Total DDTs (uncorrected)



B39-Polar Star Sediments: Lindane



B40-Polar Star Sediments: Lindane (uncorrected)

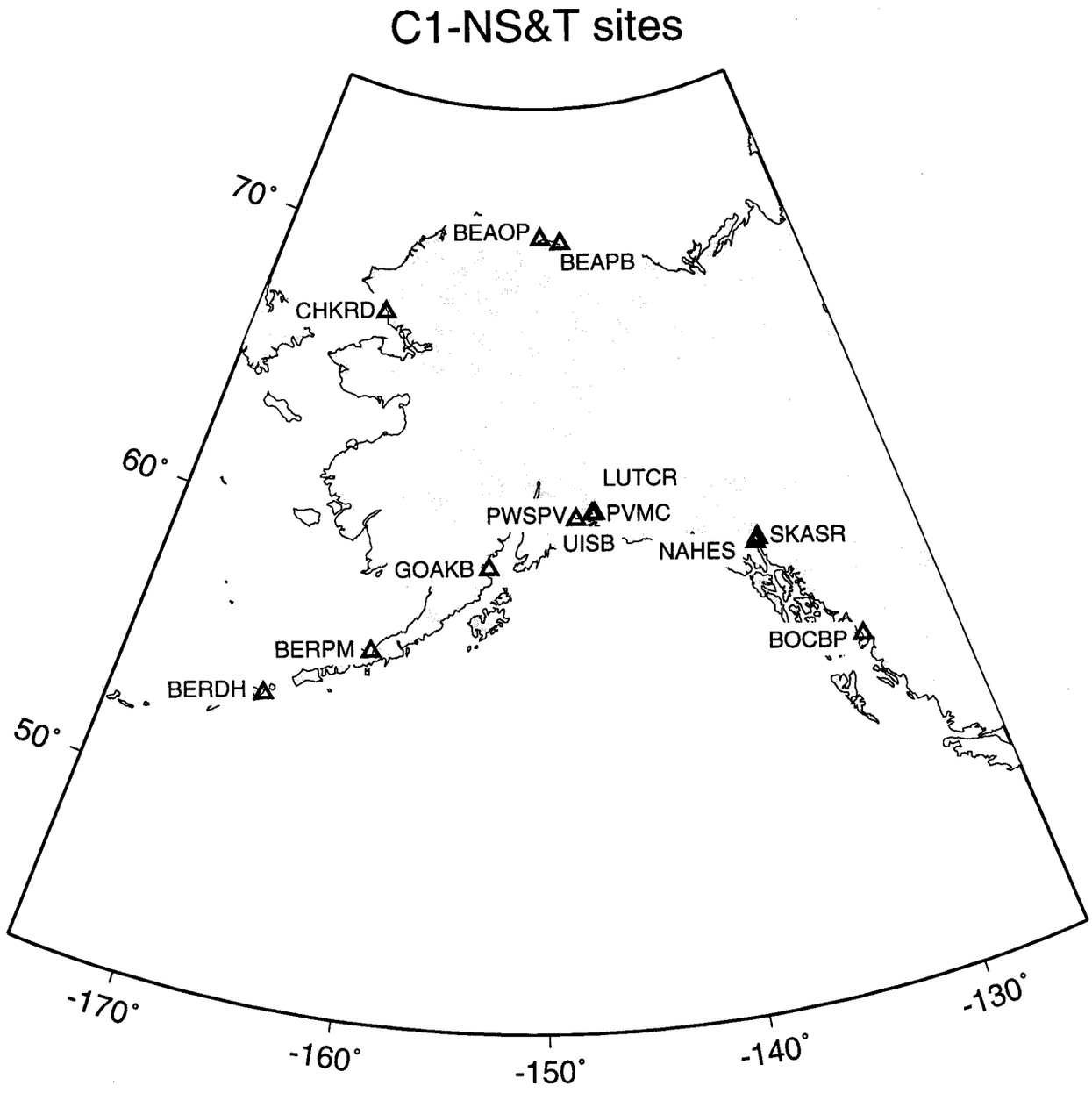


Appendix C
NS&T Program Figures

The triangles correspond to the location of the NS&T sites. The acronym placed next to the point distinguishes between Mussel Watch sites (four letters acronyms) and Benthic Surveillance sites (five letter acronyms).

In all the figures of Appendix C, the triangles correspond to the position of the sites. The circles correspond to the concentrations of the element or compound. The size of the circles is proportional to the concentration of the element or compound in the sample. The scale varies and is given in each figure.

BEAPB = Beaufort Sea, Prudhoe Bay
BEAOP = Beaufort Sea, Oliktok Point
CHKRD = Chukchi Sea, Red Dog Mine
BERDH = Bering Sea, Dutch Harbor
BERPM = Bering Sea, Port Moller
GOAKB = Gulf of Alaska, Kamishak Bay
PWSPV = Prince William Sound, Port Valdez
PVMC = Port Valdez, Mineral Creek Flats
UISB = Unakwit Inlet, Siwash Bay
LUTCR = Lutak Inlet, Chilkoot River Mouth
NAHES = Nahku Bay, East Side
SKASR = Skagway, Skagway River
BOCBP = Bocca de Quadra, Bacrian Point


C1-NS&T sites
70°
60°
50°
-170°
-160°
-150°
-140°
-130°
BEAOP
BEAPB
CHKRD
LUTCR
PWSPV
PVMC
UISB
NAHES
SKASR
GOAKB
BERPM
BOCBP
BERDH

Trace Metals (Concentrations in ppm dry weight)

For the trace metals, all the concentrations are grain size corrected.

Figures C3 and C4 are at two different scales. In C4 the highest concentration in C3 was excluded.

Figures C6 and C7 are at two different scales. In C7 the highest concentration in C6 was excluded.

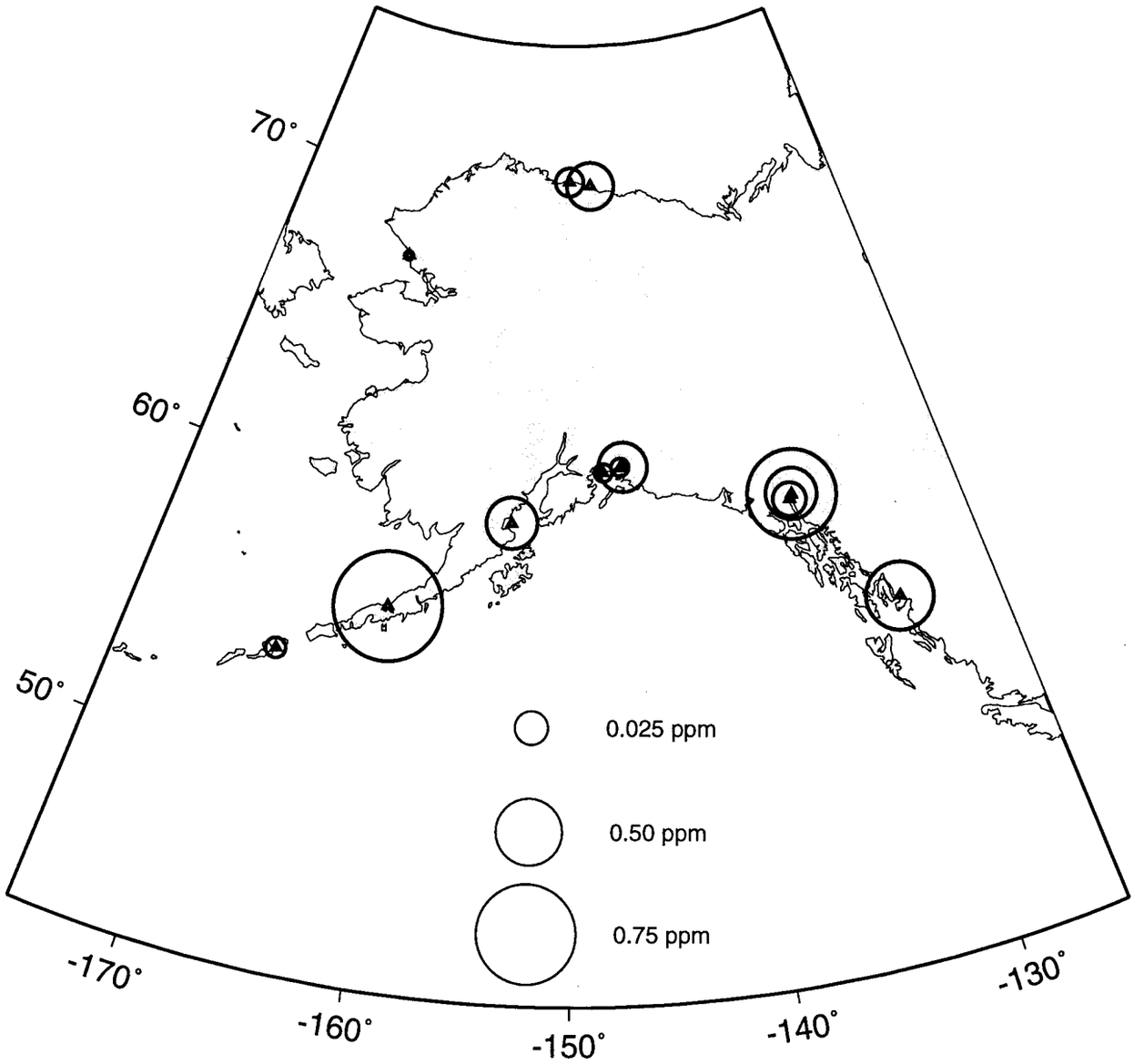
Figures C10 and C11 are at two different scales. In C11 the highest concentration in C10 was excluded.

Figures C13 and C14 are at two different scales. In C14 the highest concentration in C13 was excluded.

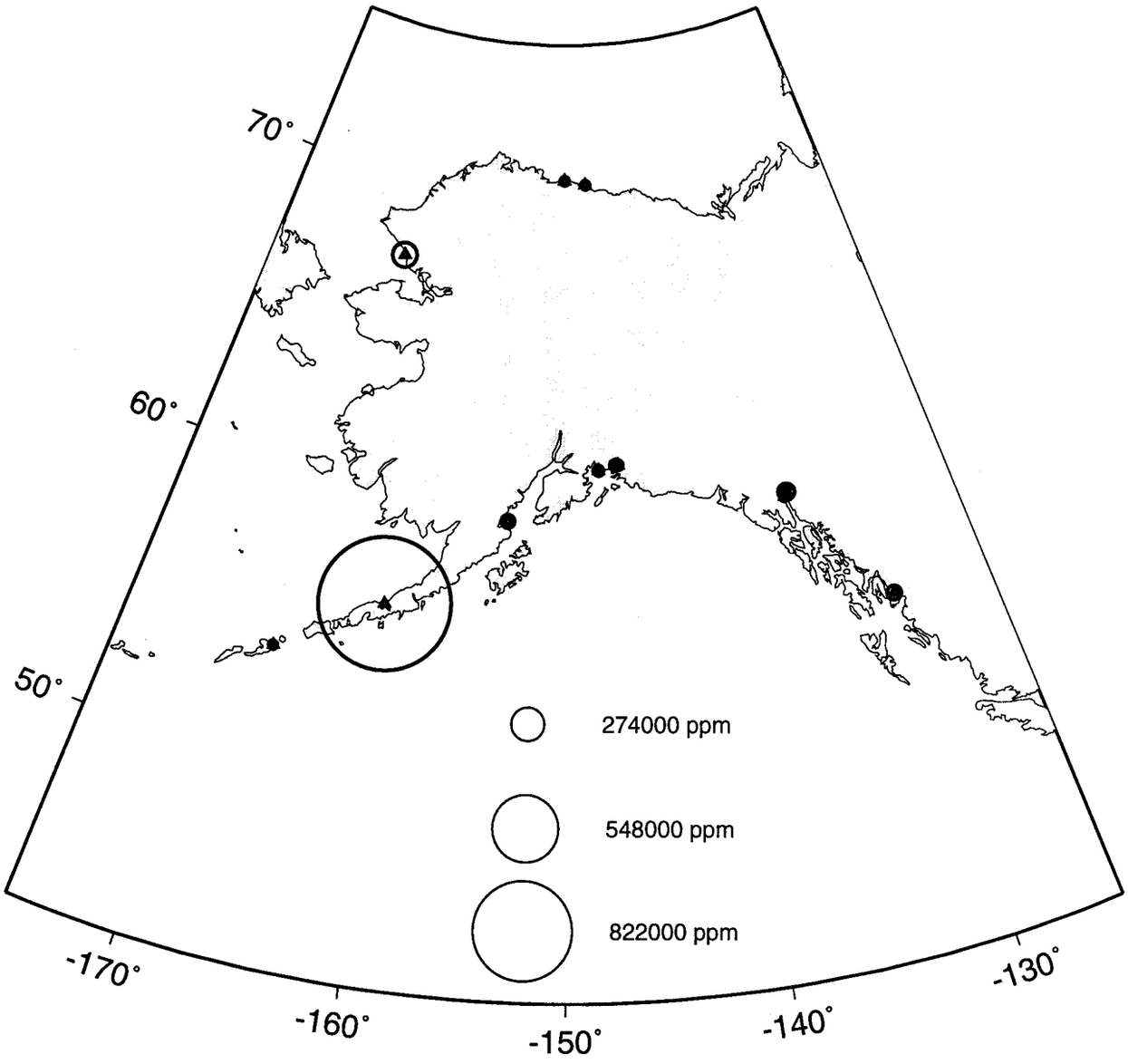
Figures C17 and C18 are at two different scales. In C18 the highest concentration in C17 was excluded.

Figures C23 and C24 are at two different scales. In C24 the highest concentration in C23 was excluded.

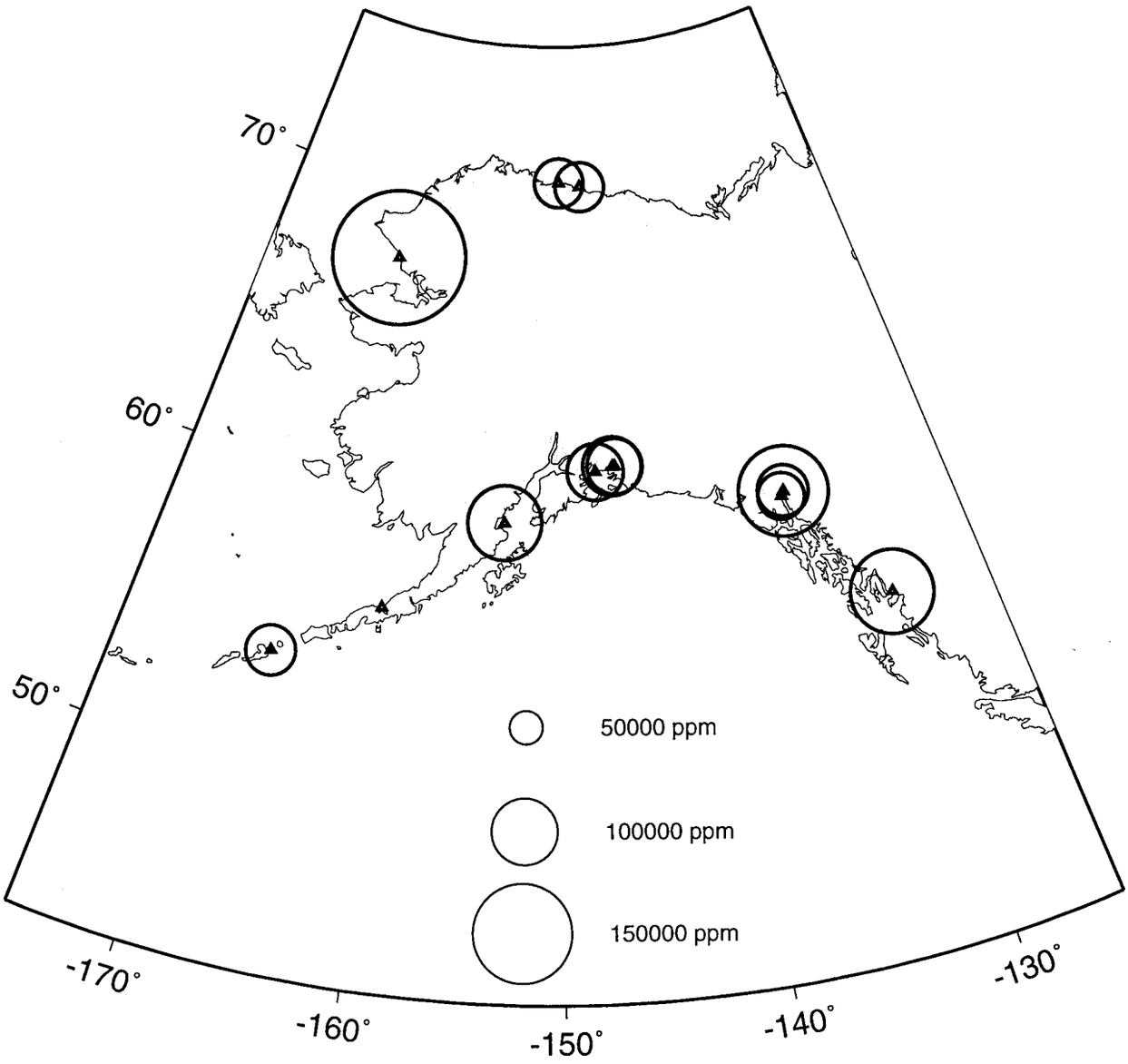
C2-NS&T Sediments: Silver



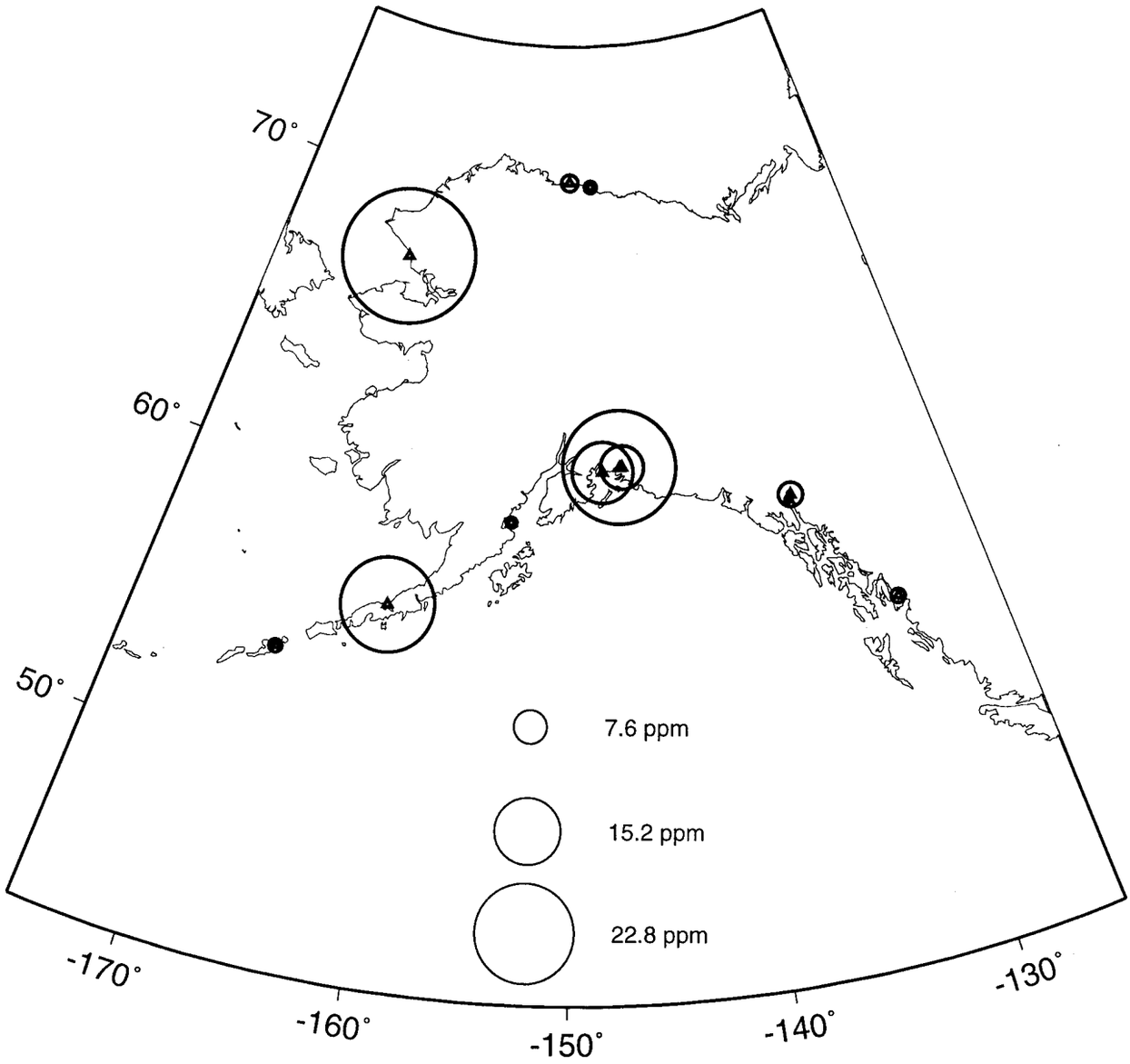
C3-NS&T Sediments: Aluminum 1



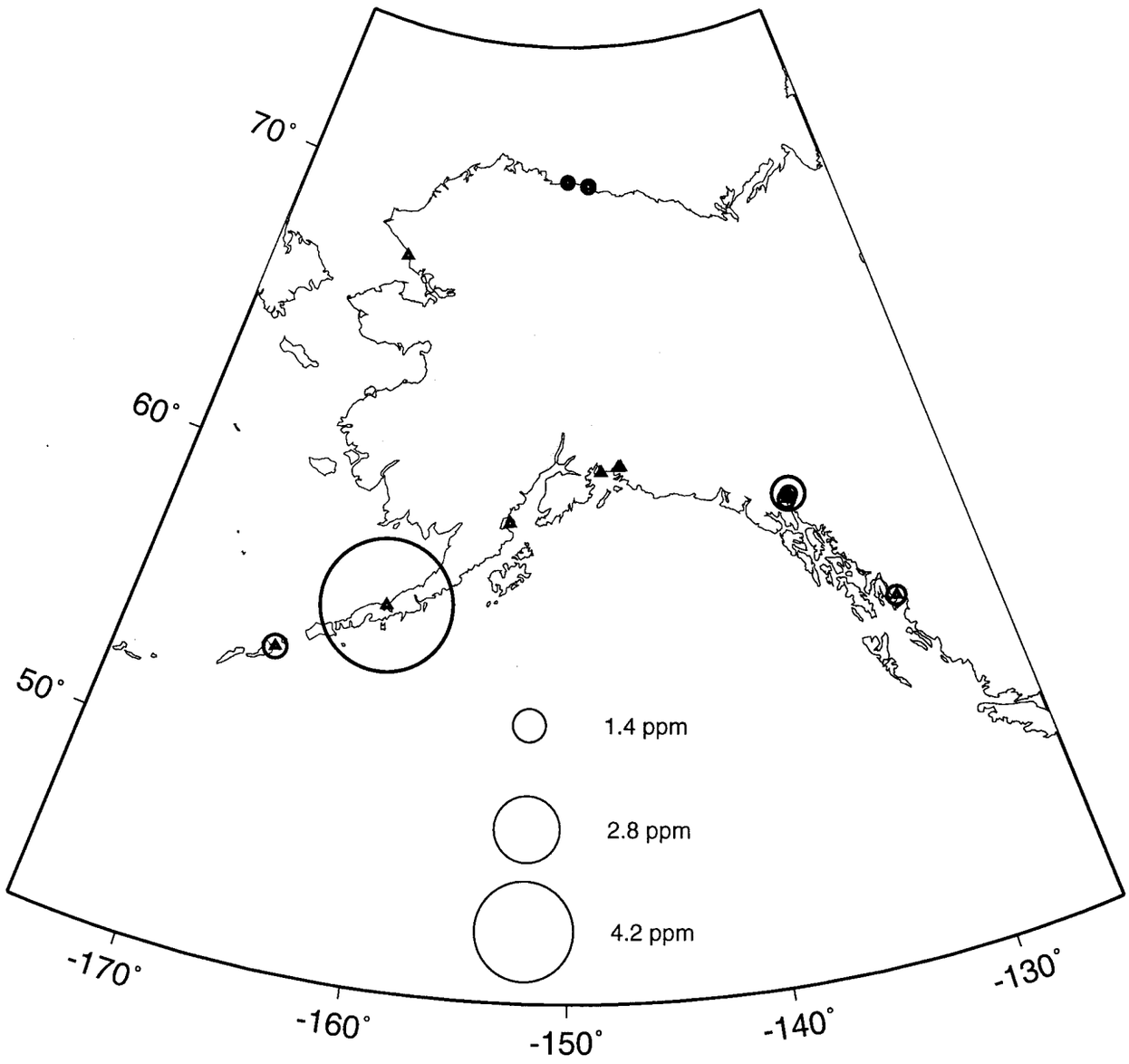
C4-NS&T Sediments: Aluminum 2



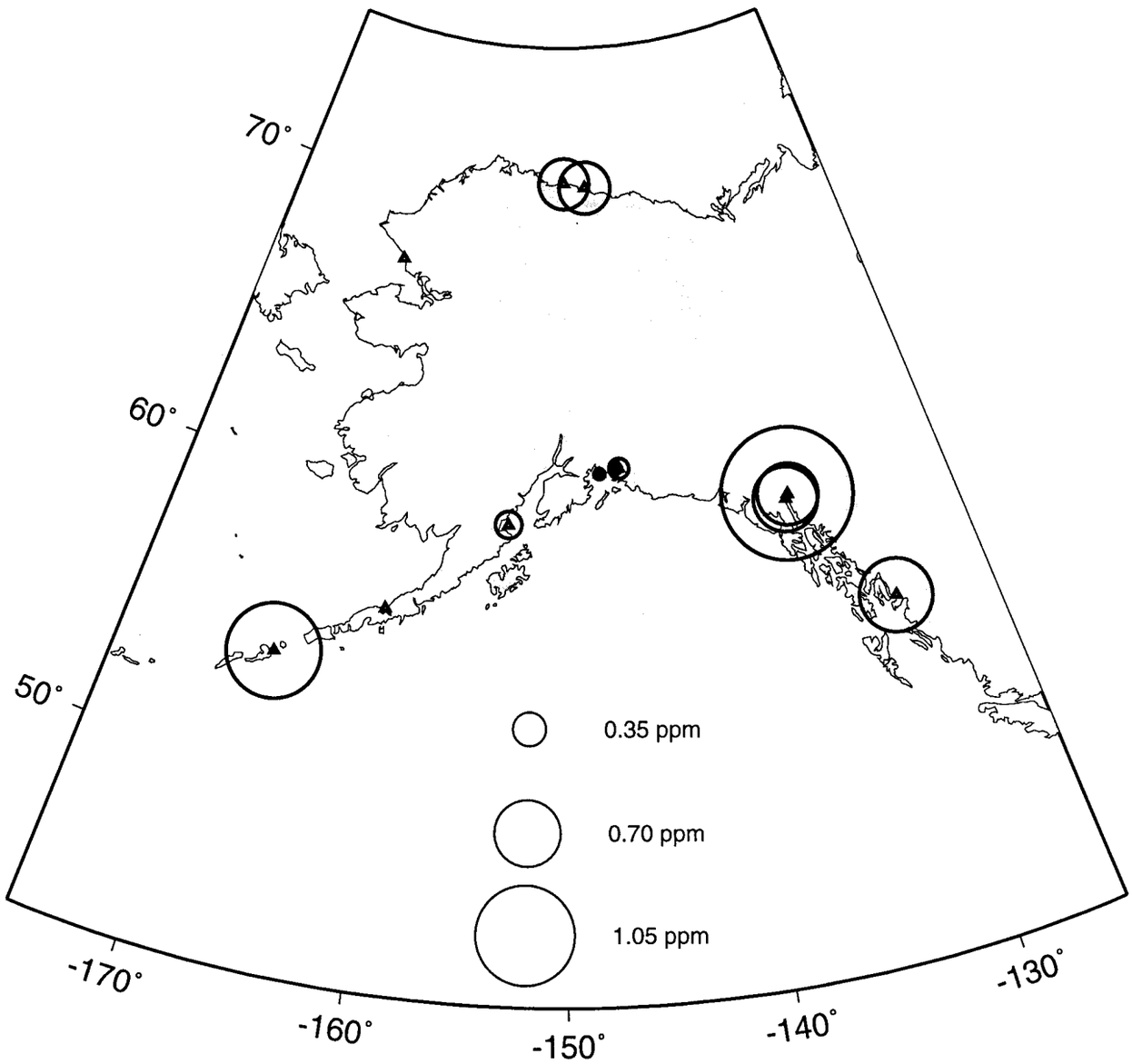
C5-NS&T Sediments: Arsenic



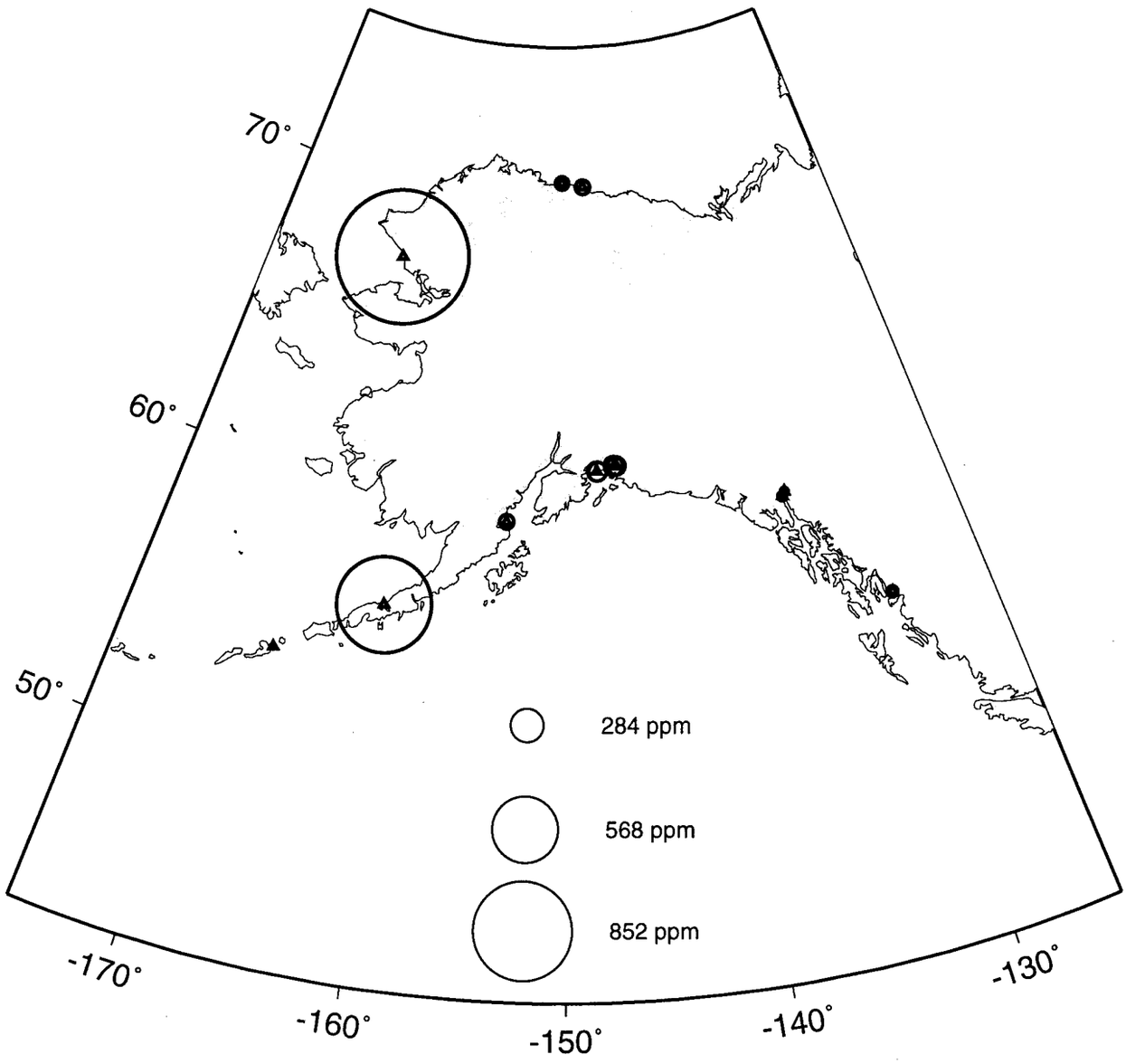
C6-NS&T Sediments: Cadmium 1



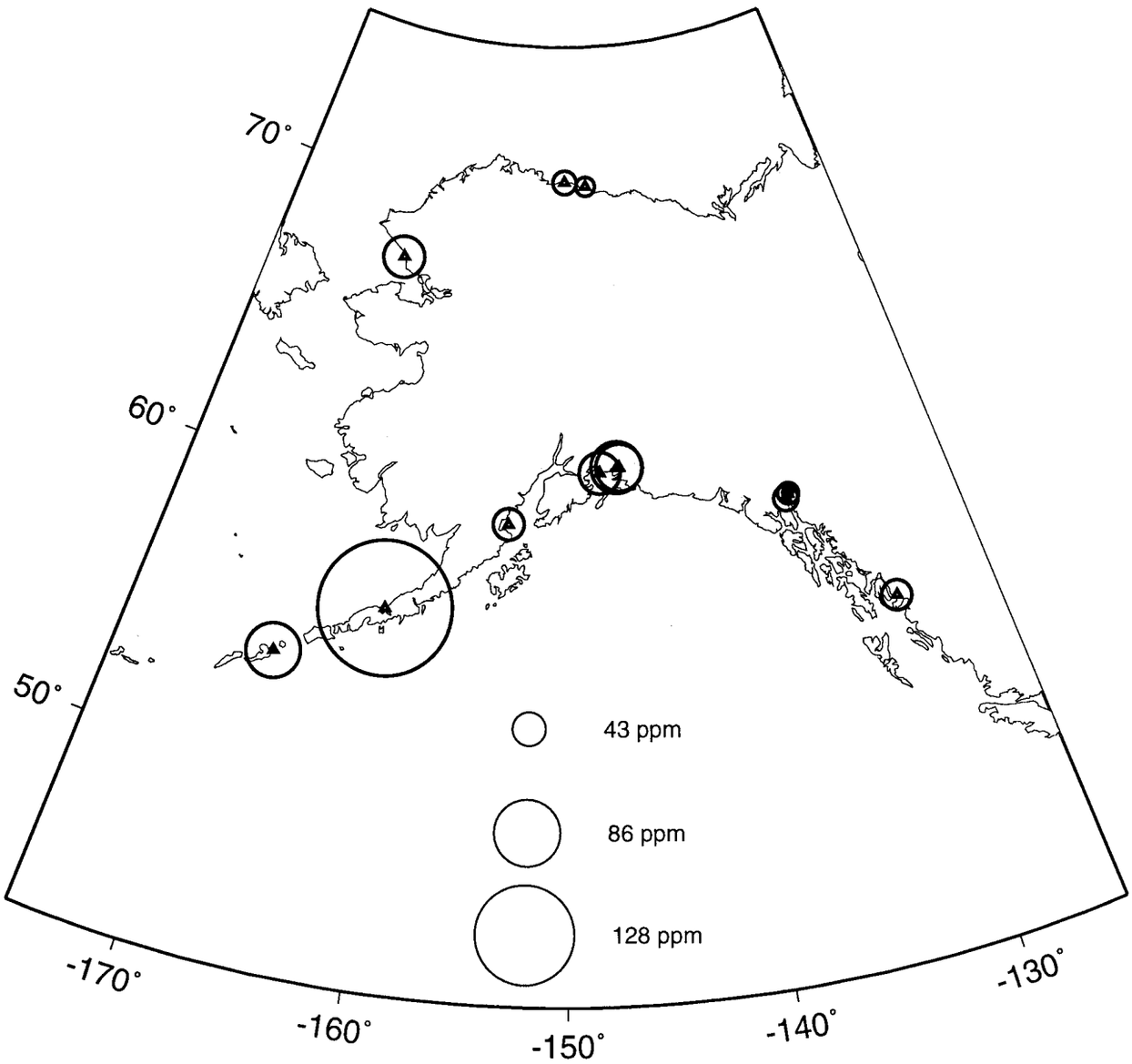
C7-NS&T Sediments: Cadmium 2



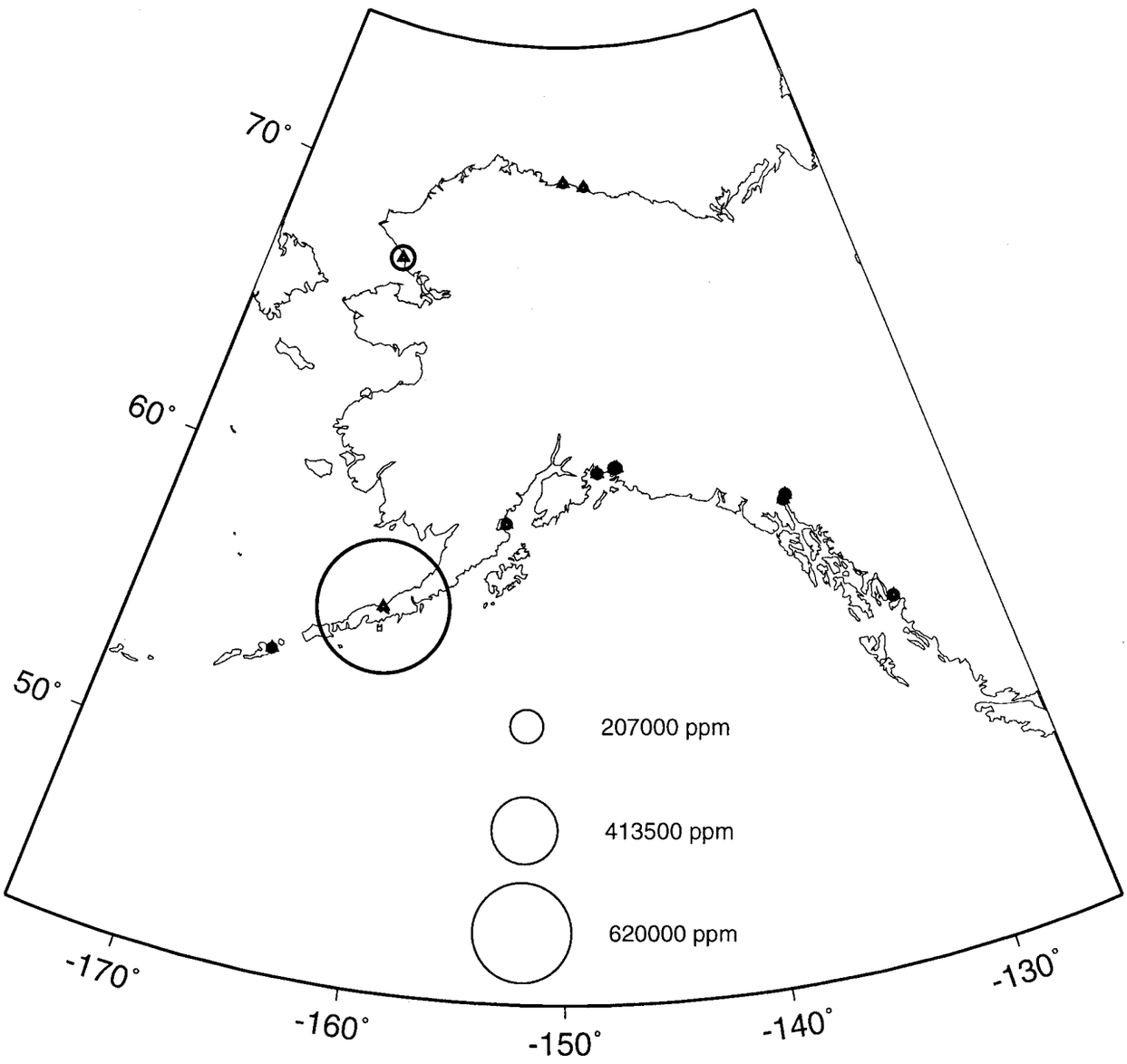
C8-NS&T Sediments: Chromium



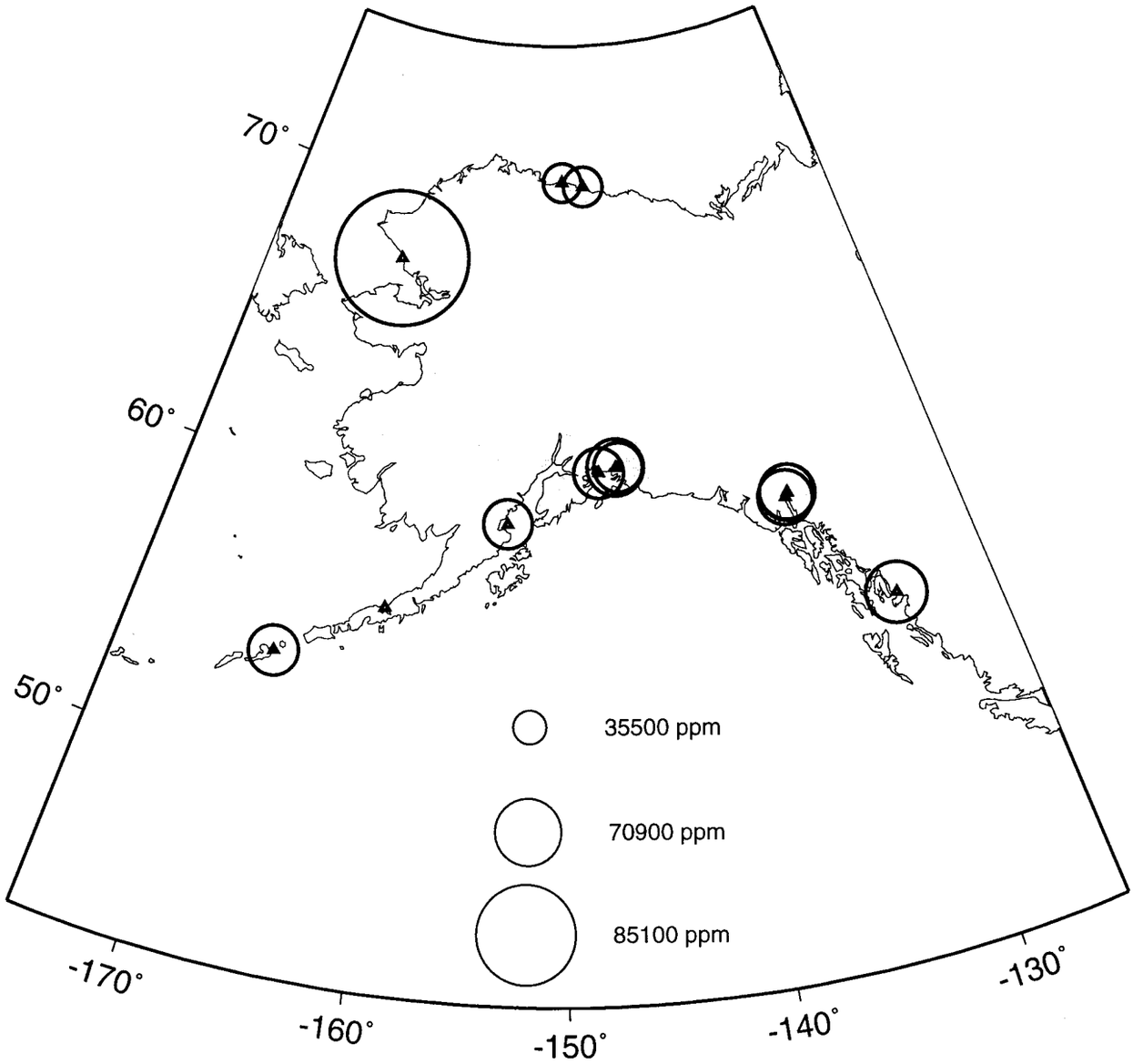
C9-NS&T Sediments: Copper



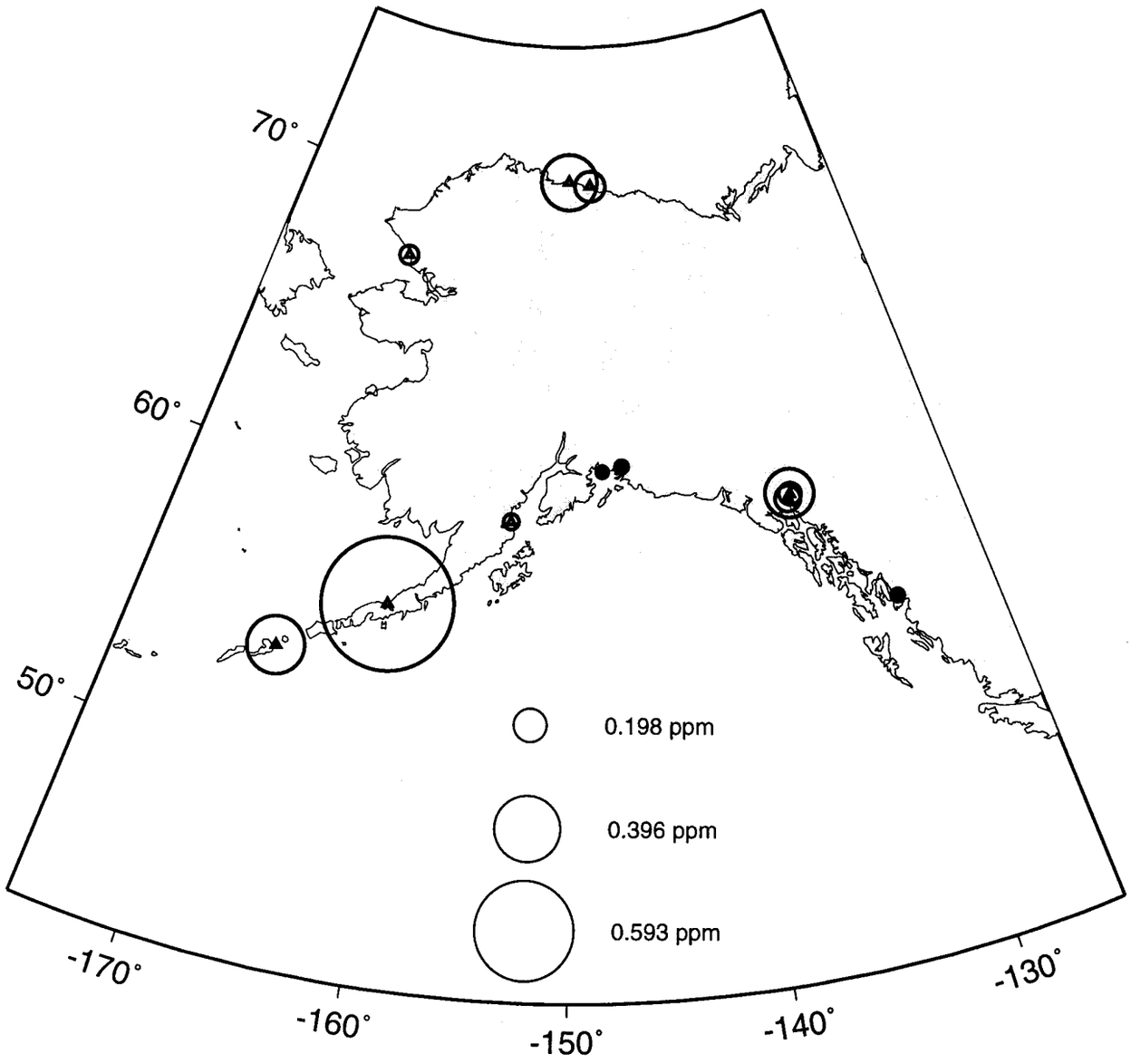
C10-NS&T Sediments: Iron 1



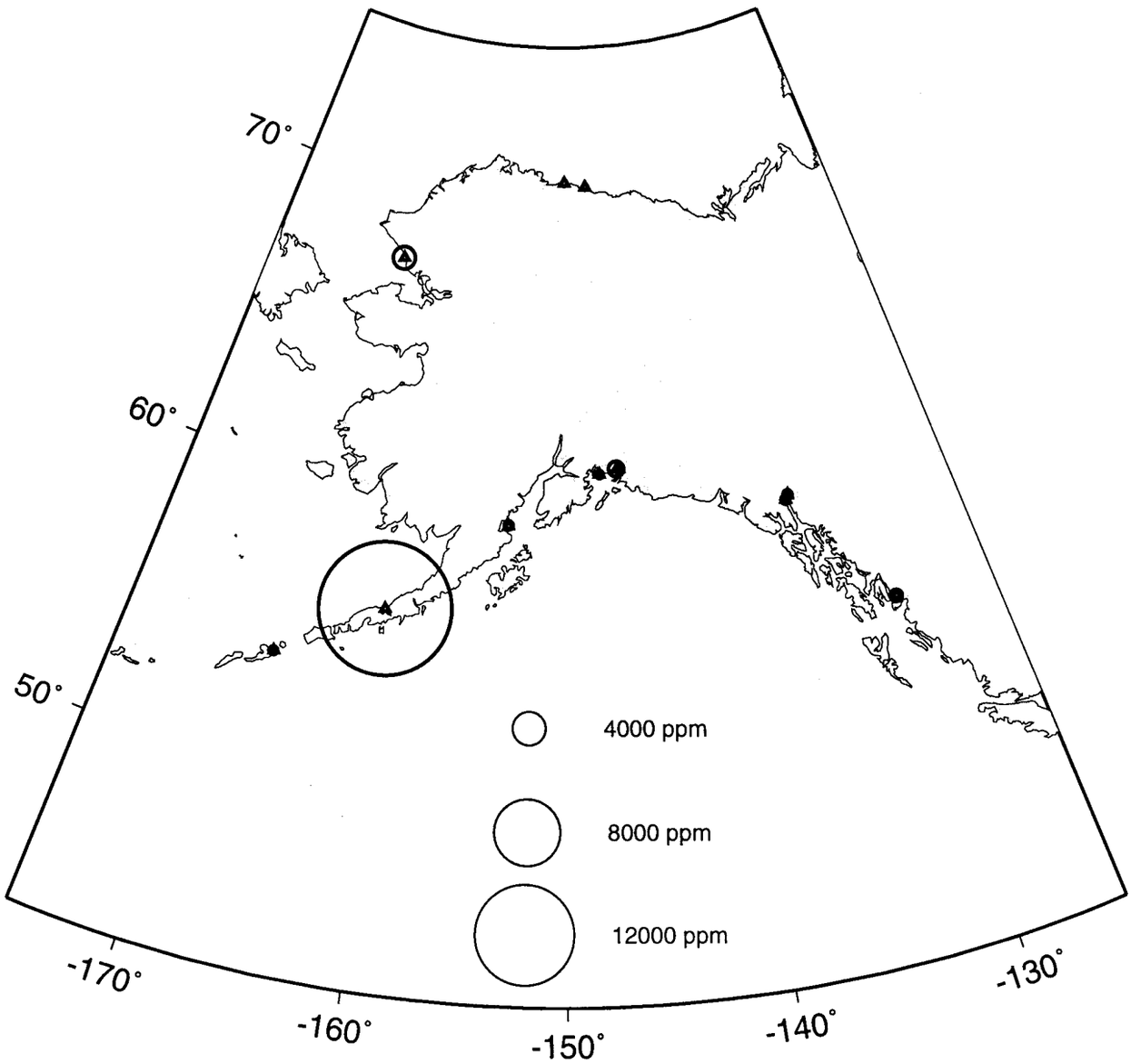
C11-NS&T Sediments: Iron 2



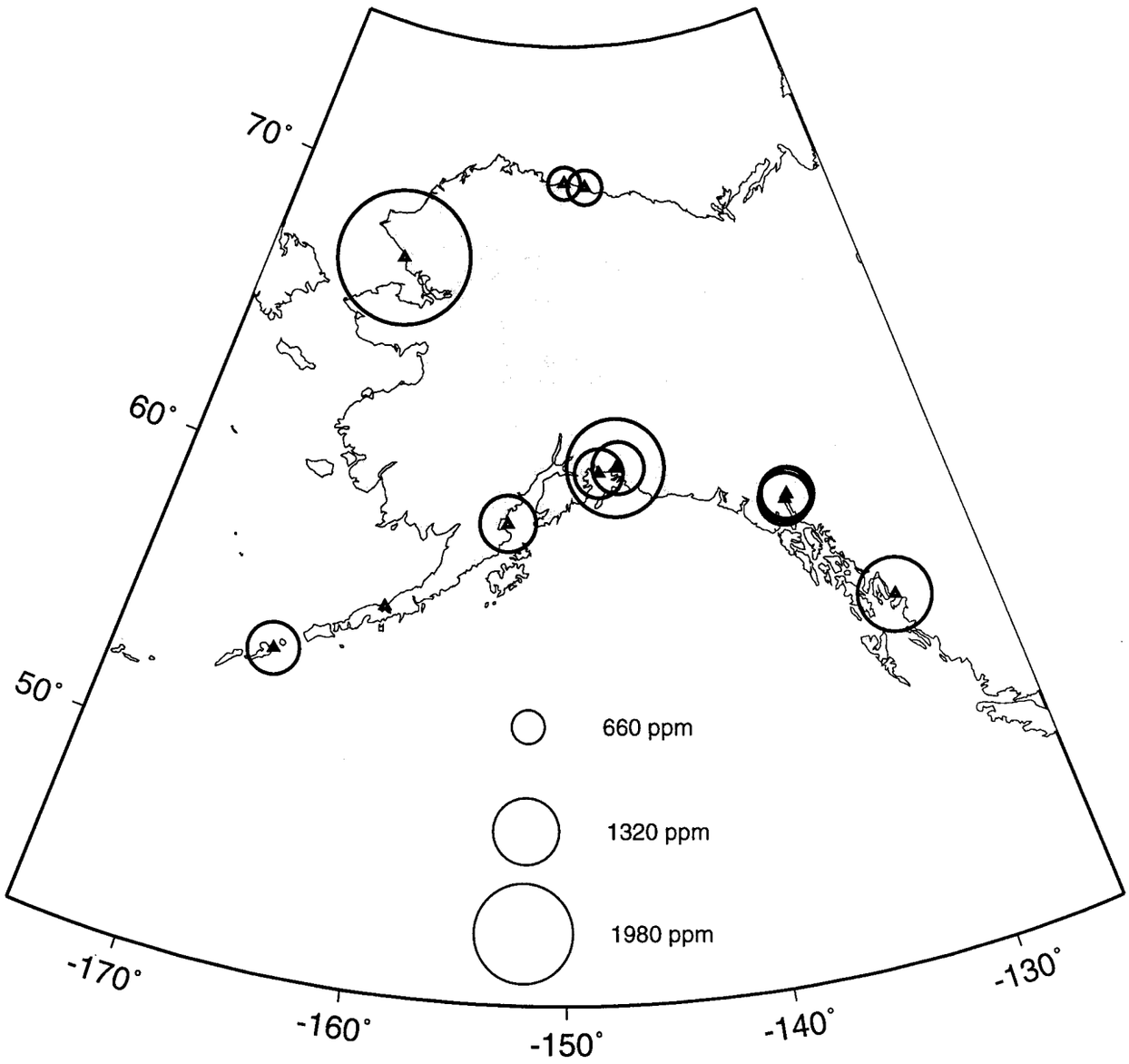
C12-NS&T Sediments: Mercury



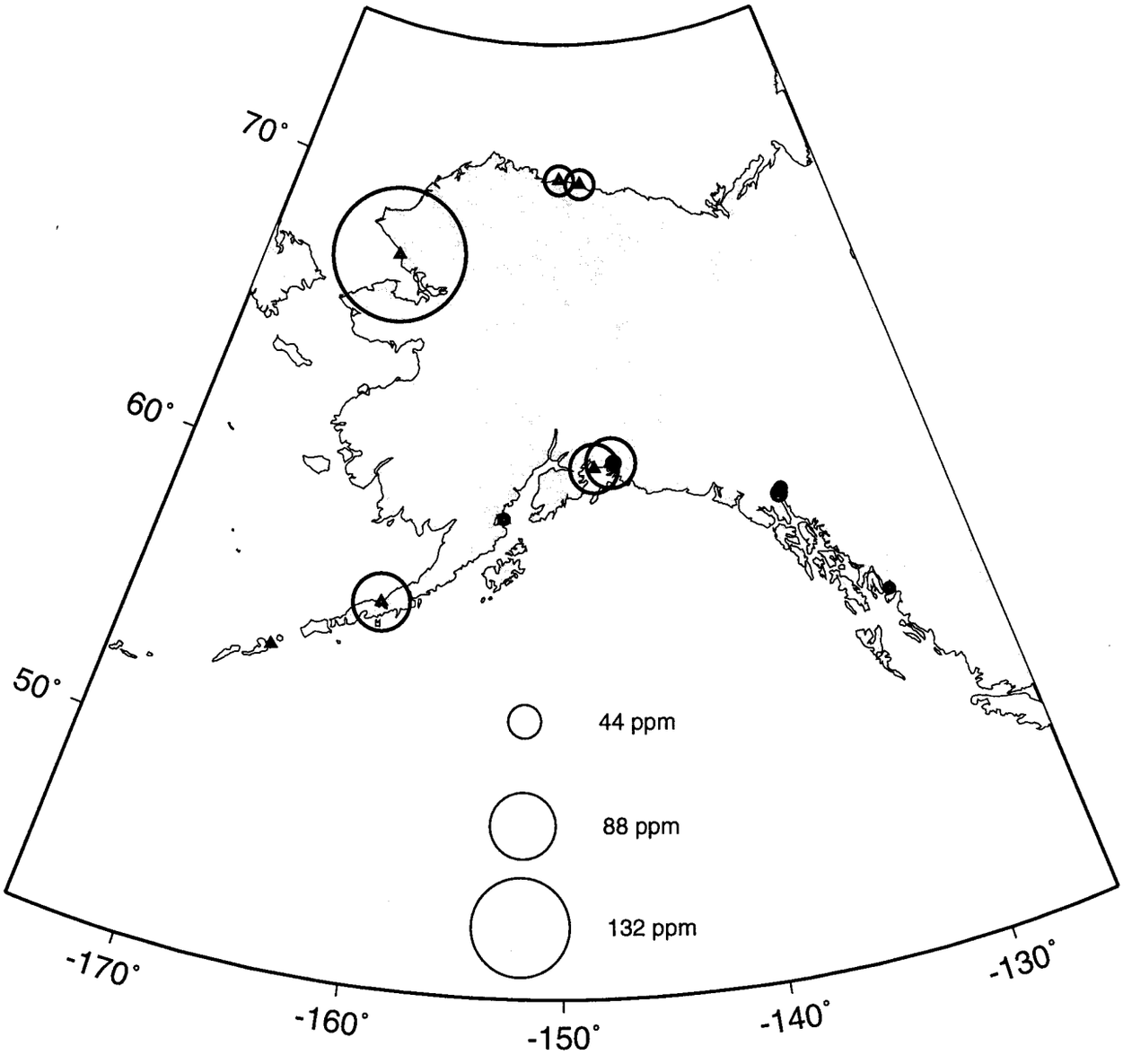
C13-NS&T Sediments: Mangenese 1



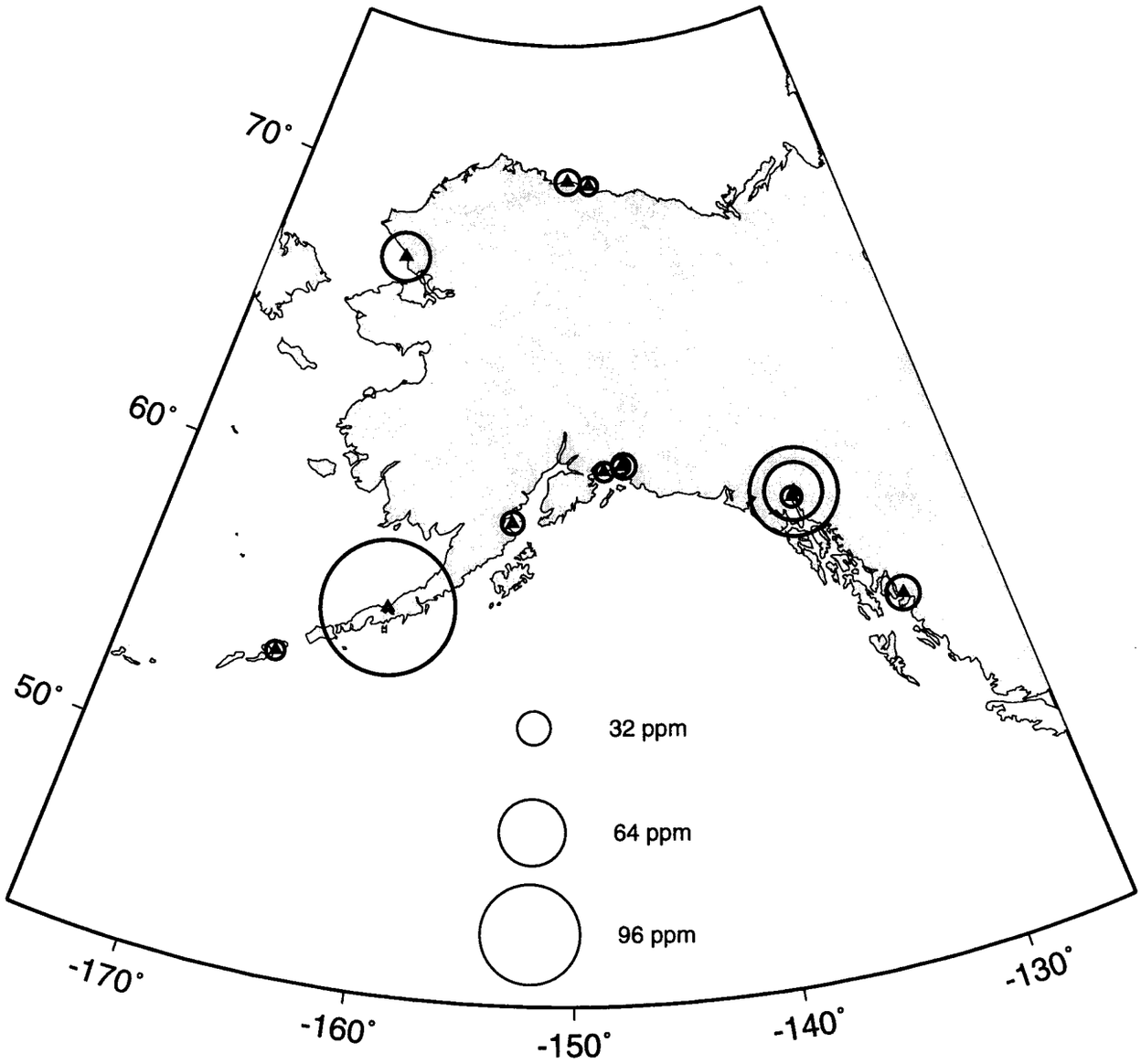
C14-NS&T Sediments: Mangenese 2



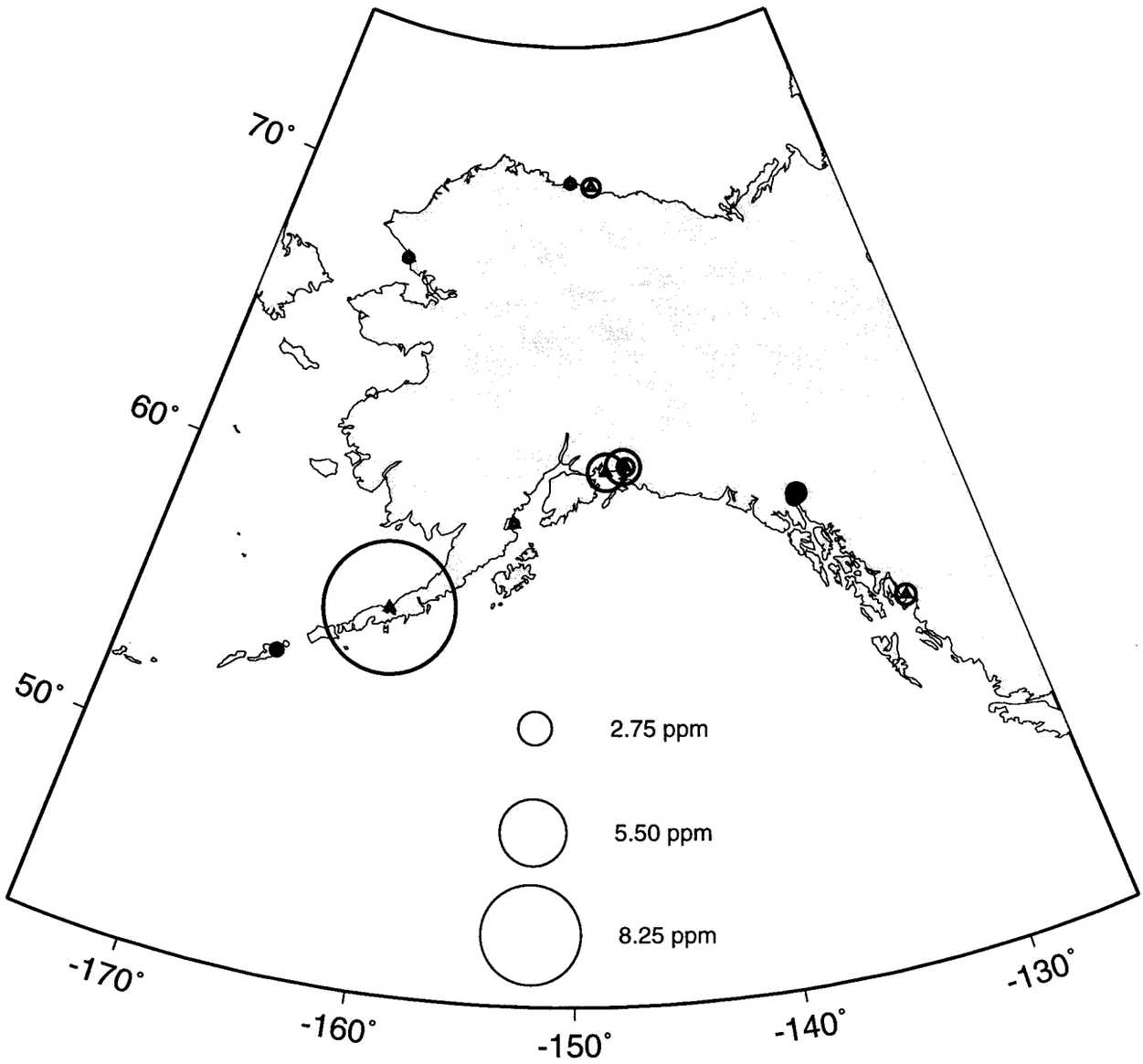
C15-NS&T Sediments: Nickel



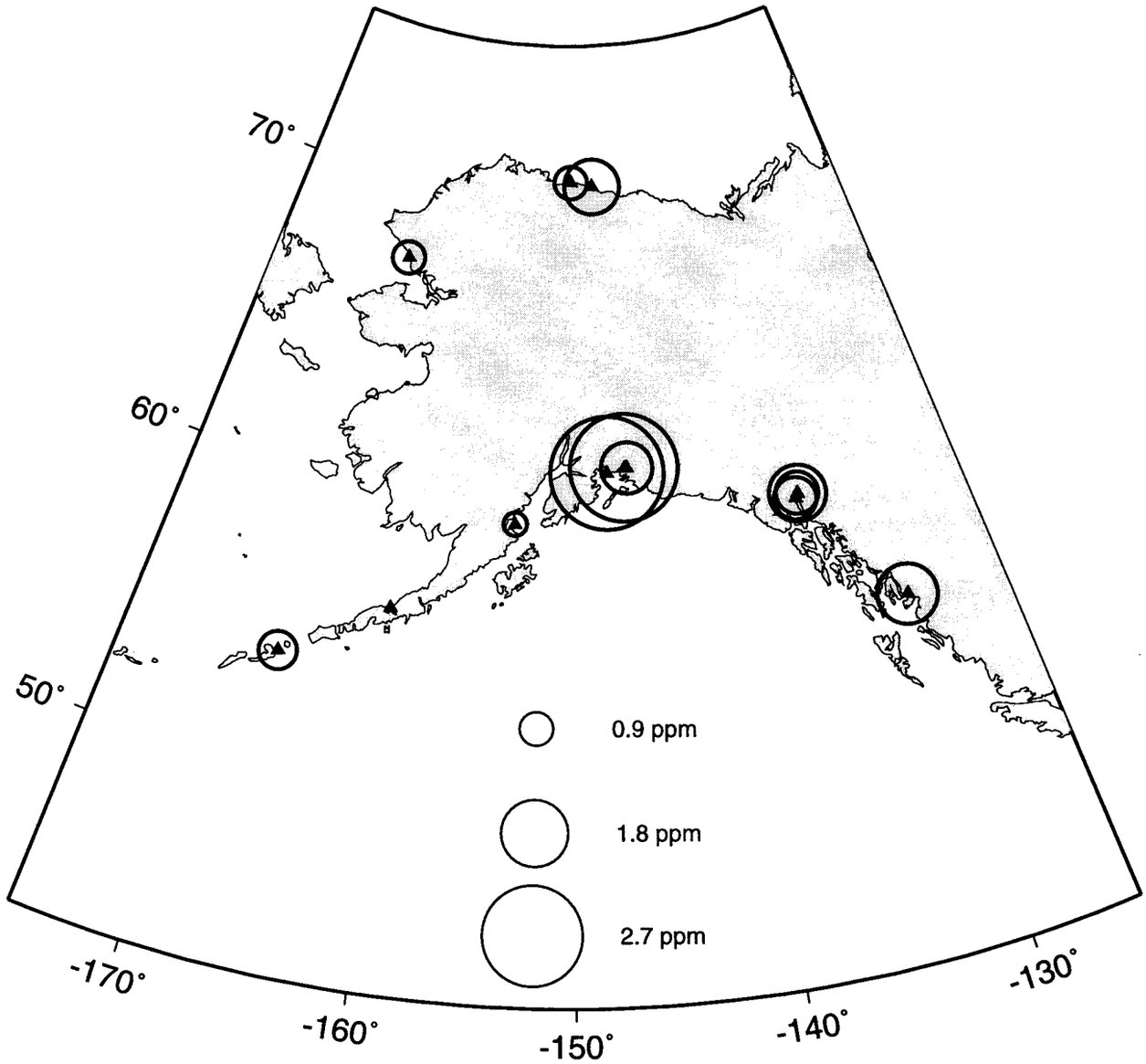
C16-NS&T Sediments: Lead



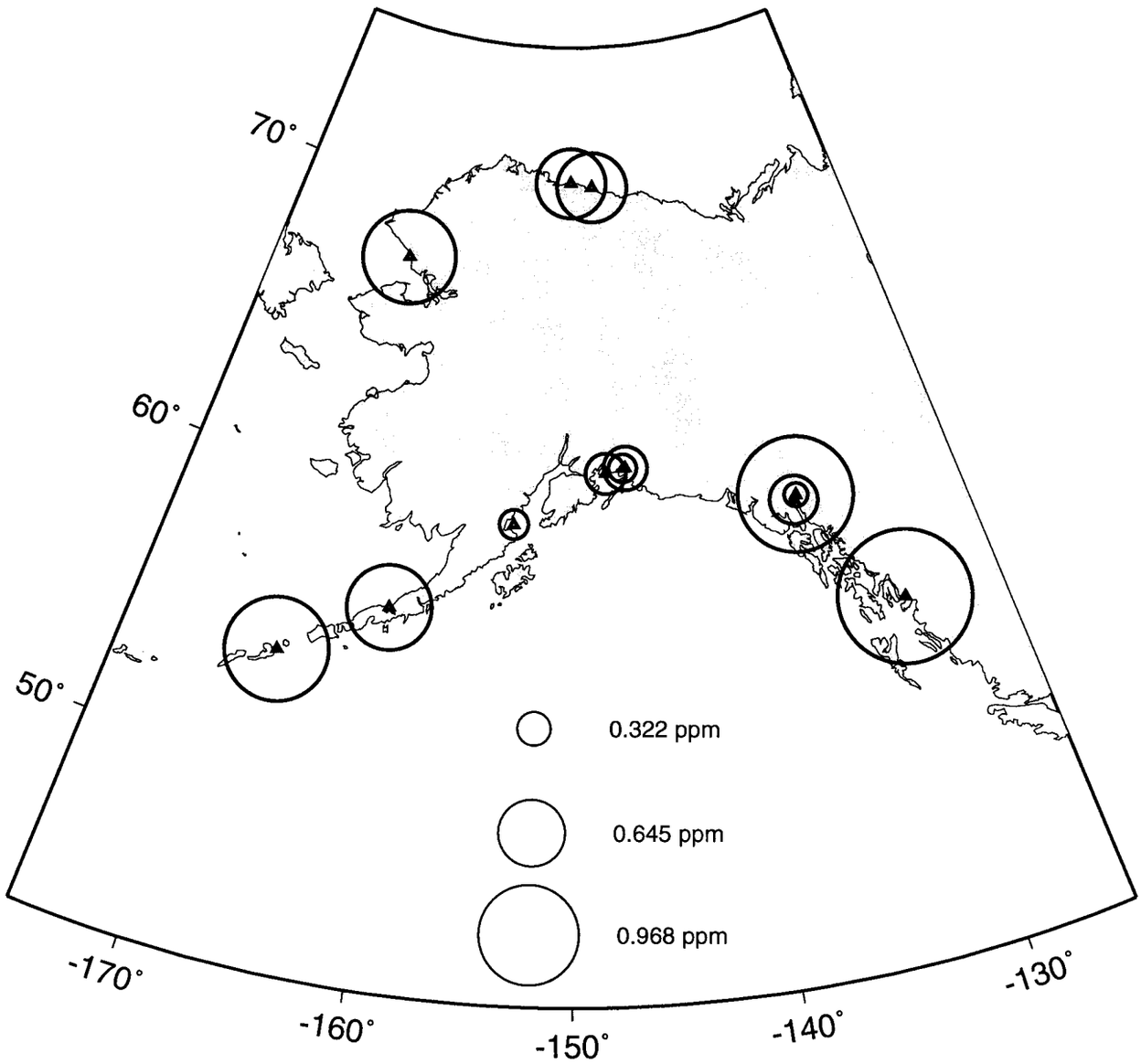
C17-NS&T Sediments: Antimony 1



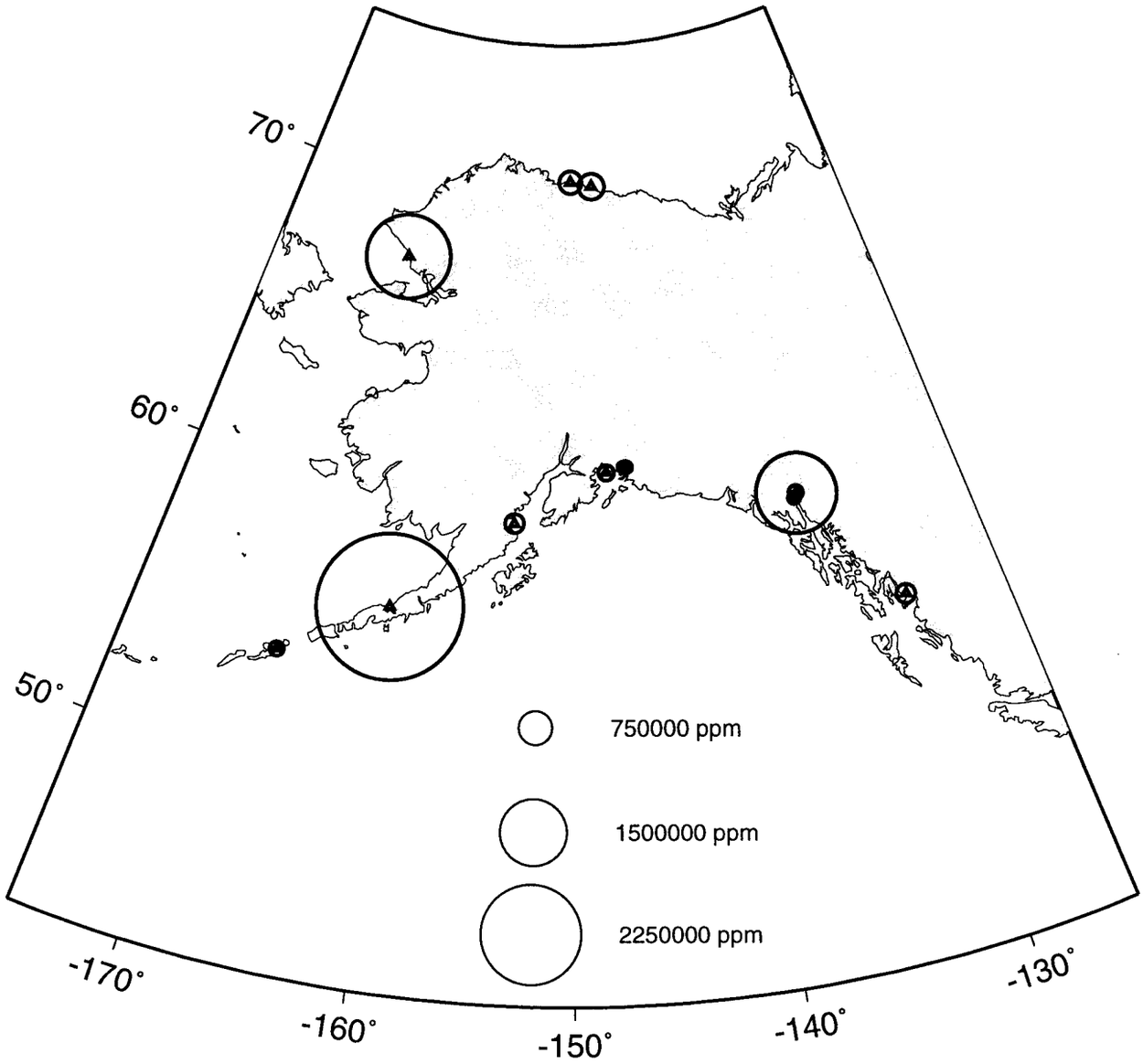
C18-NS&T Sediments: Antimony 2



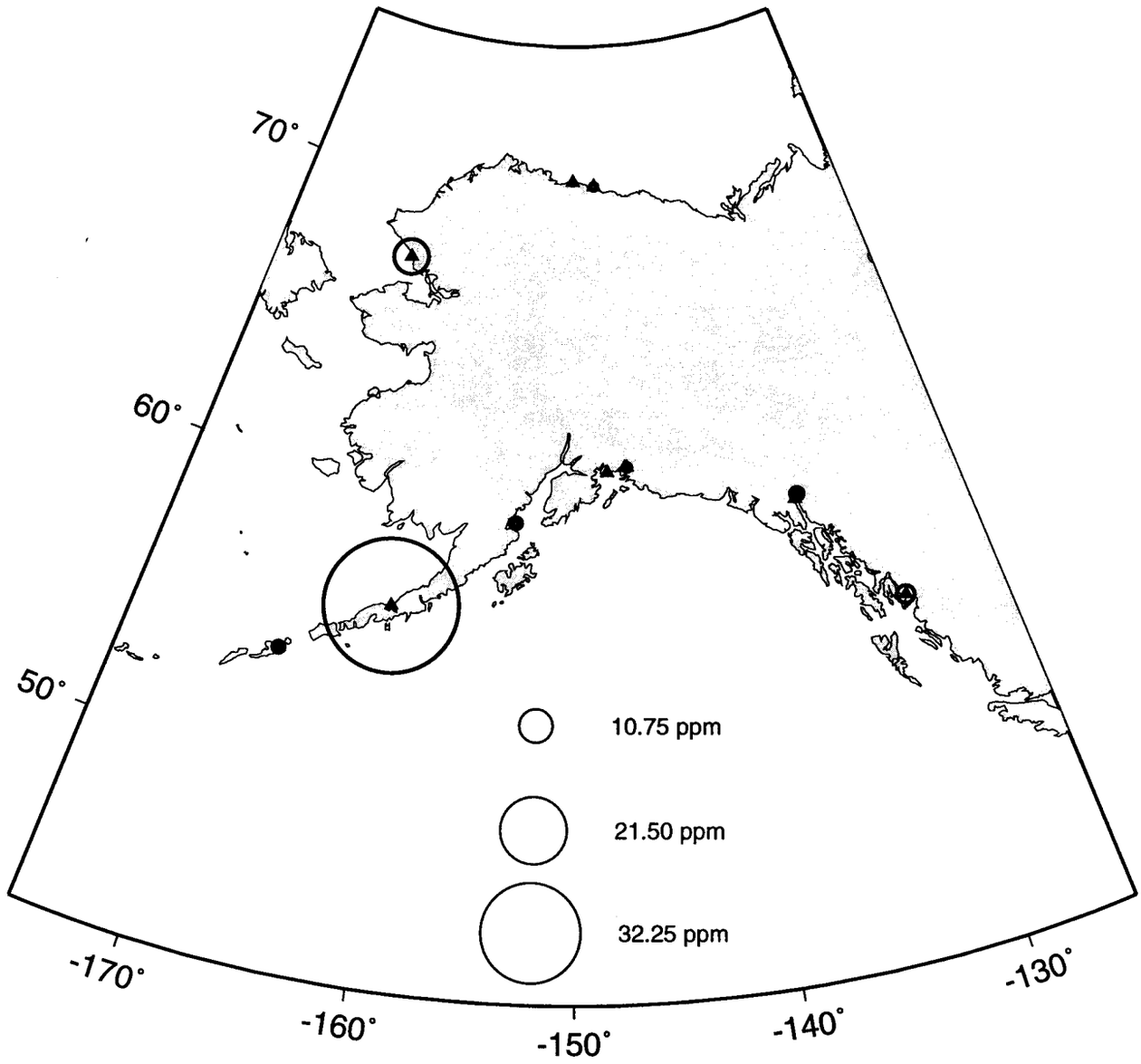
C19-NS&T Sediments: Selenium



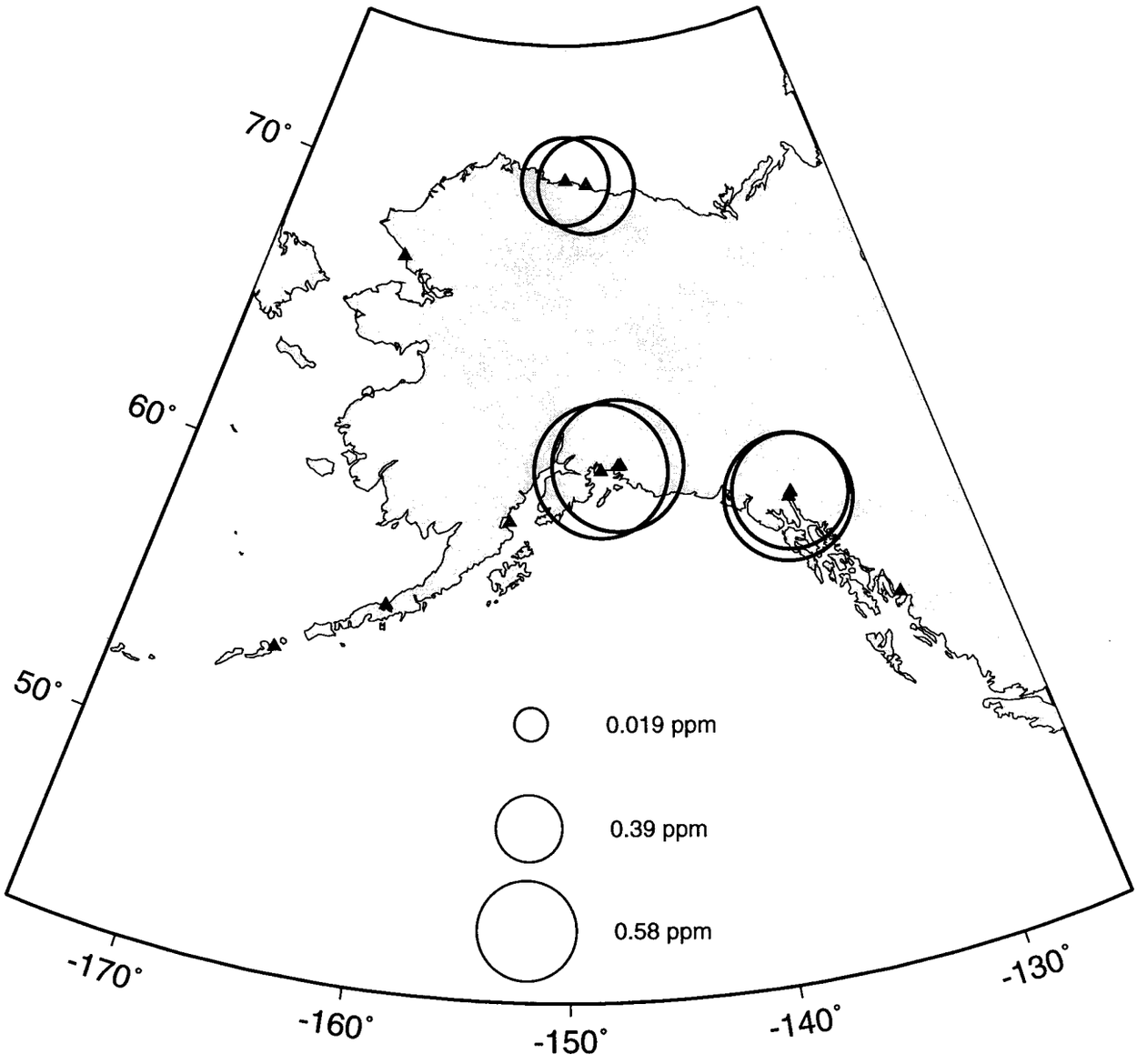
C20-NS&T Sediments: Silicium



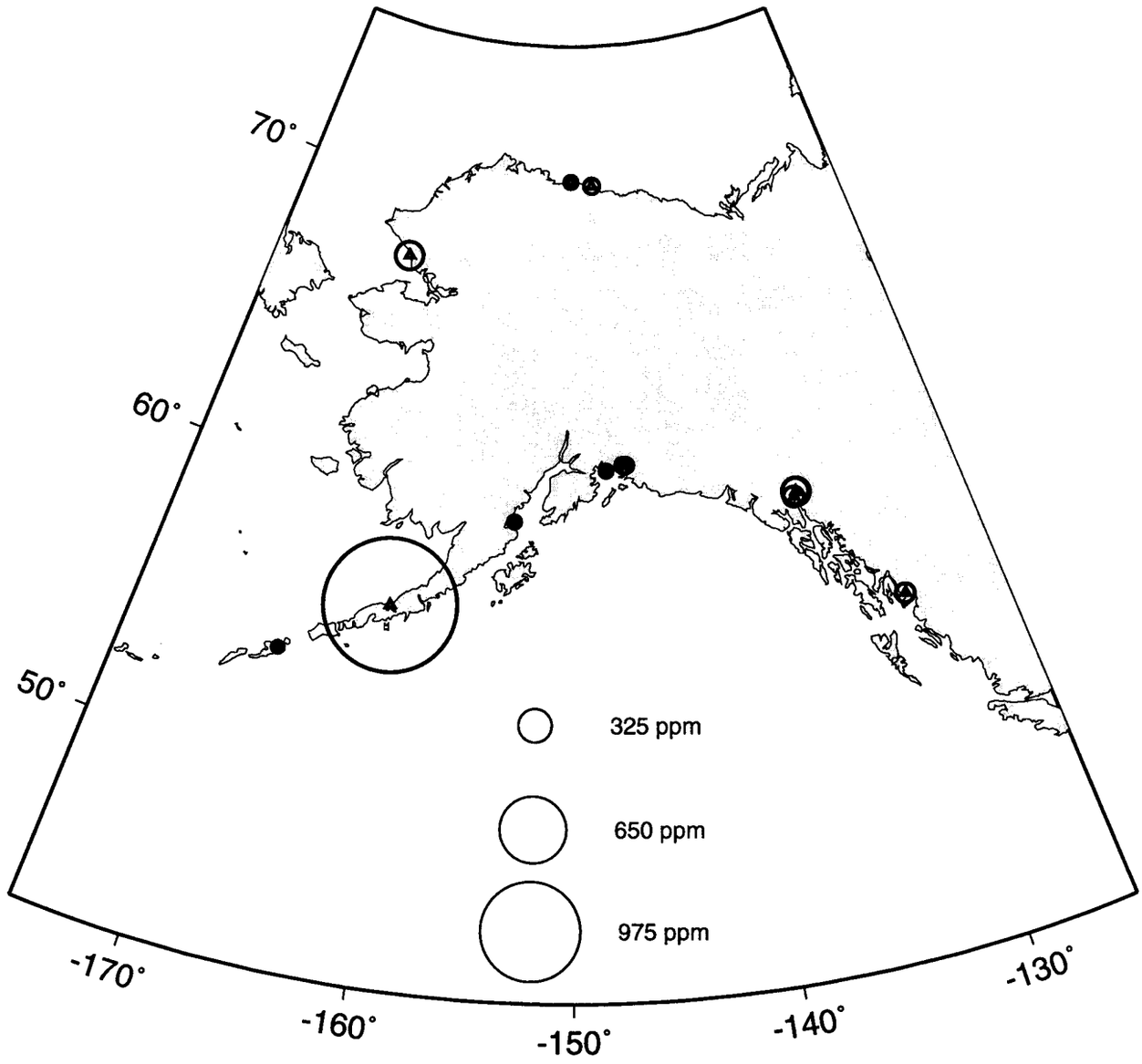
C21-NS&T Sediments: Tin



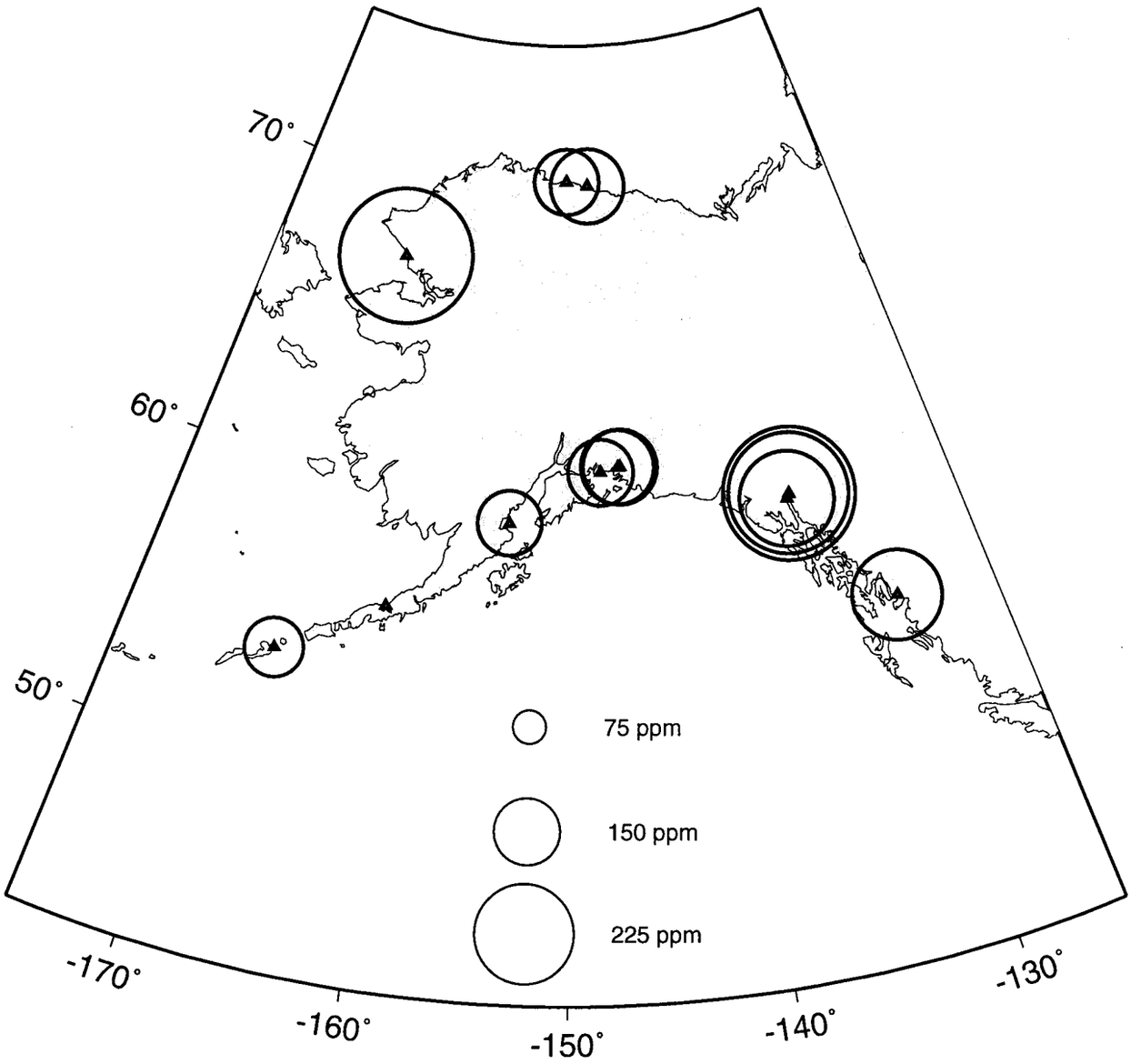
C22-NS&T Sediments: Thallium



C23-NS&T Sediments: Zinc 1



C24-NS&T Sediments: Zinc 2



Organic Compounds (Concentrations in ng/g dry weight)

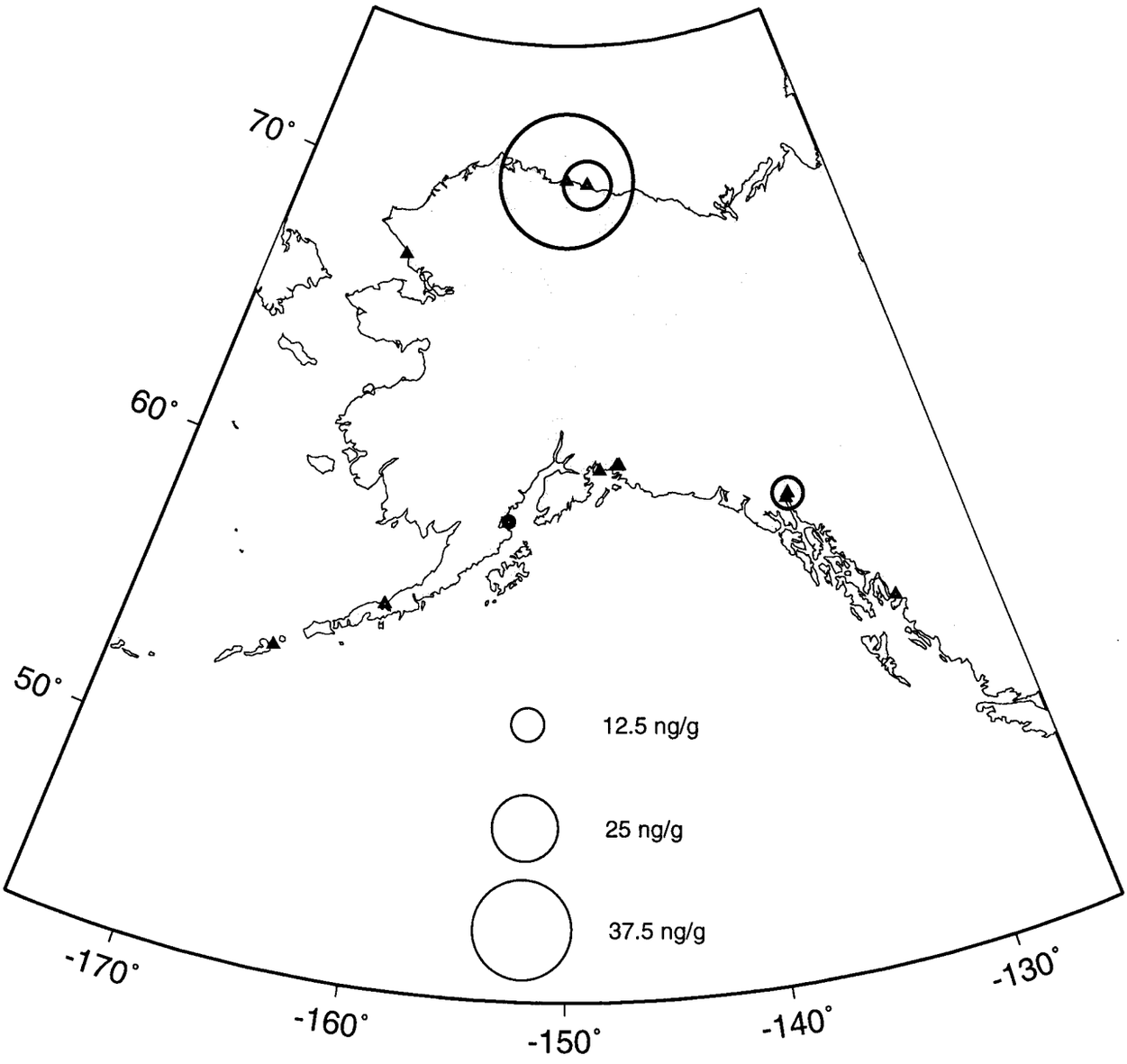
All the data used to construct these figures are corrected for grain size variability.

Total Phenant/Anthra: Total of the phenanthrenes and anthracenes.

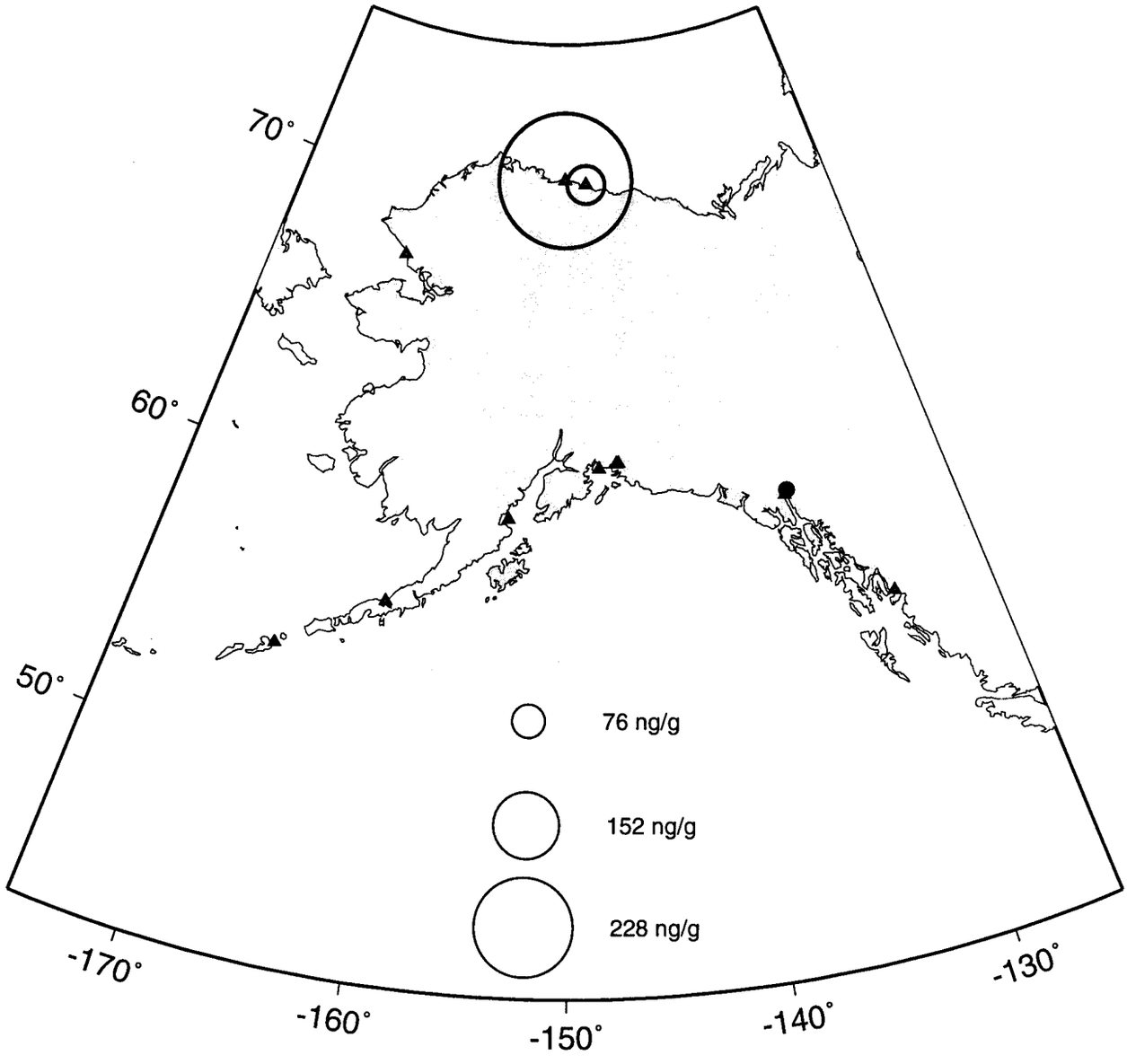
Total PCBs = Sum of the Di, Tri, Tetra, Penta, Hexa, Hepta, Octa, and Nonachlorobiphenyl analyzed.

Total PCB Congeners = Sum of the PCBs congeners analyzed (PCB 8, 18, 28, 44, 52, 66, 101, 105, 107, 118, 126, 136, 153, 170, 180, 187, 195, 206, and 209).

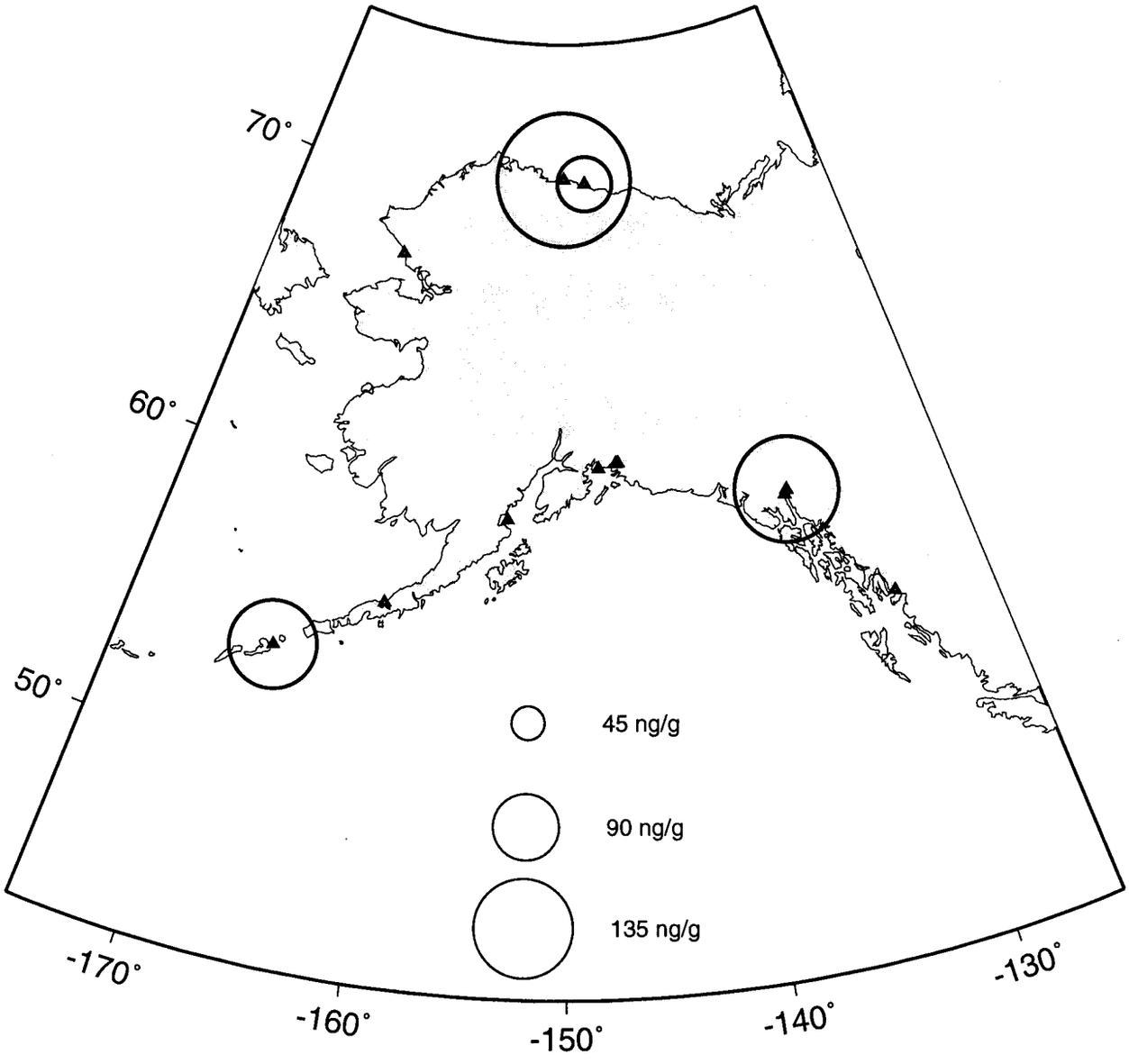
C25-NS&T Sediments: Naphtalene



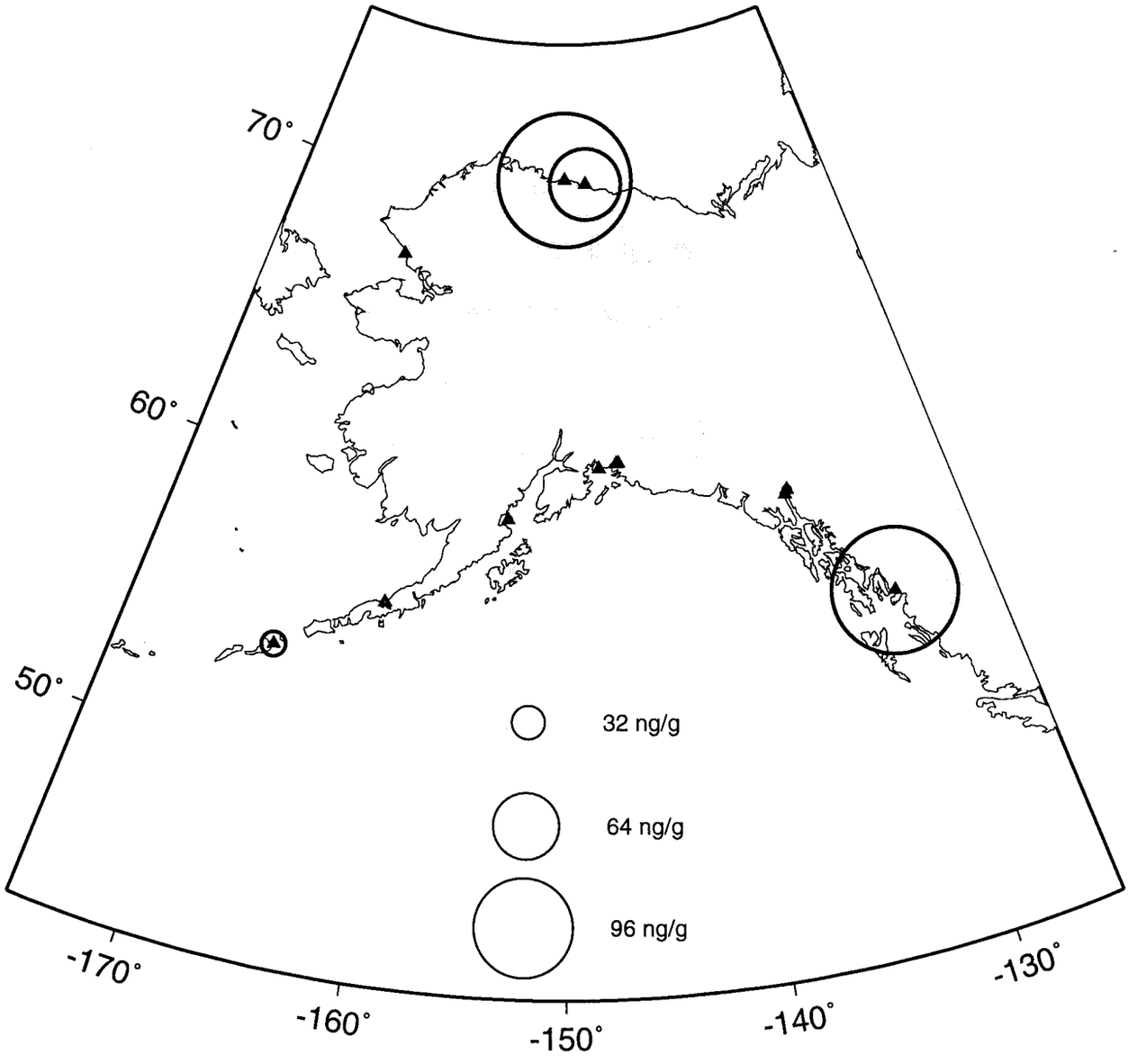
C26-NS&T Sediments: Total Naphtalenes



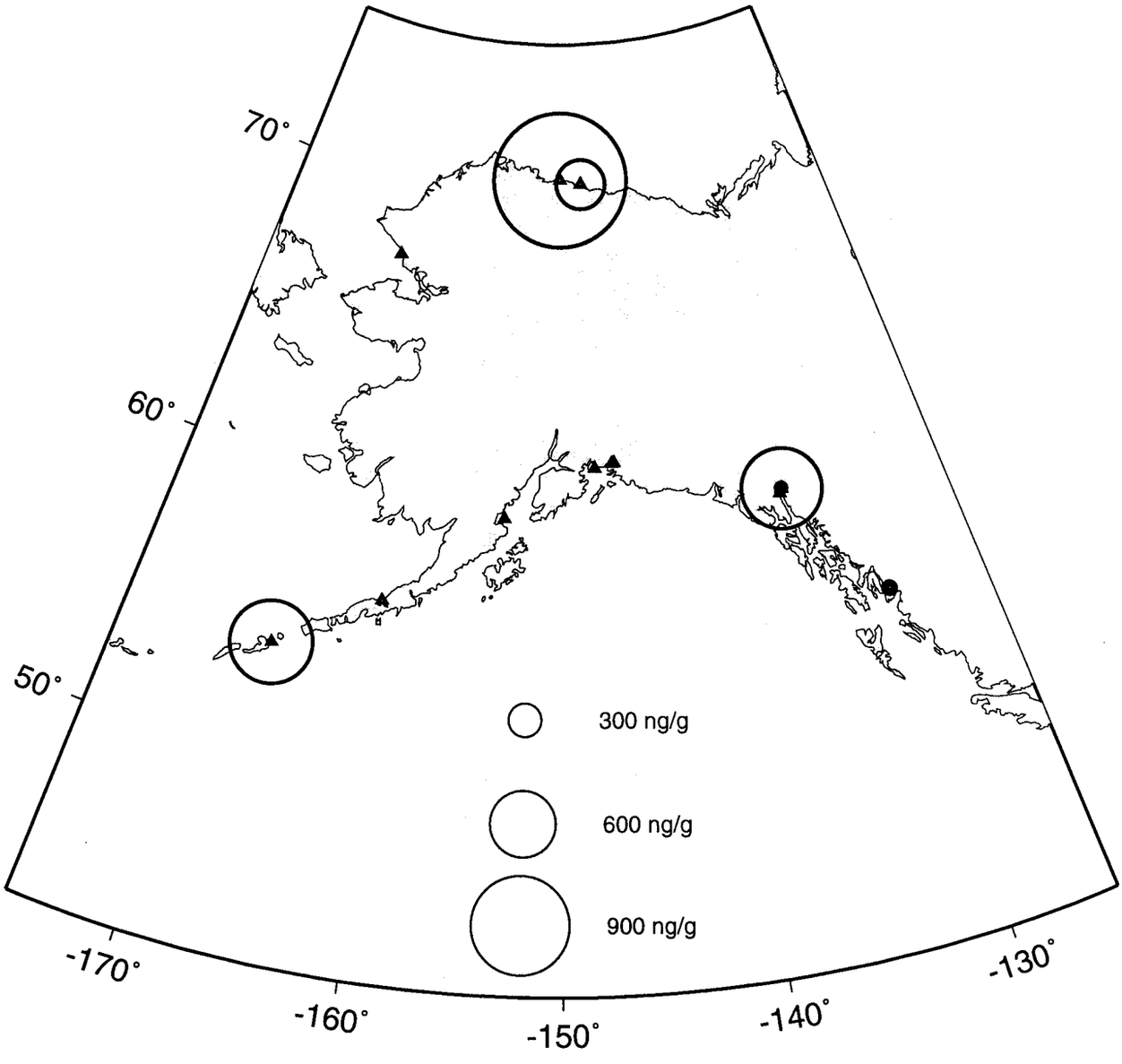
C27-NS&T Sediments: Total Phenant/Anthra



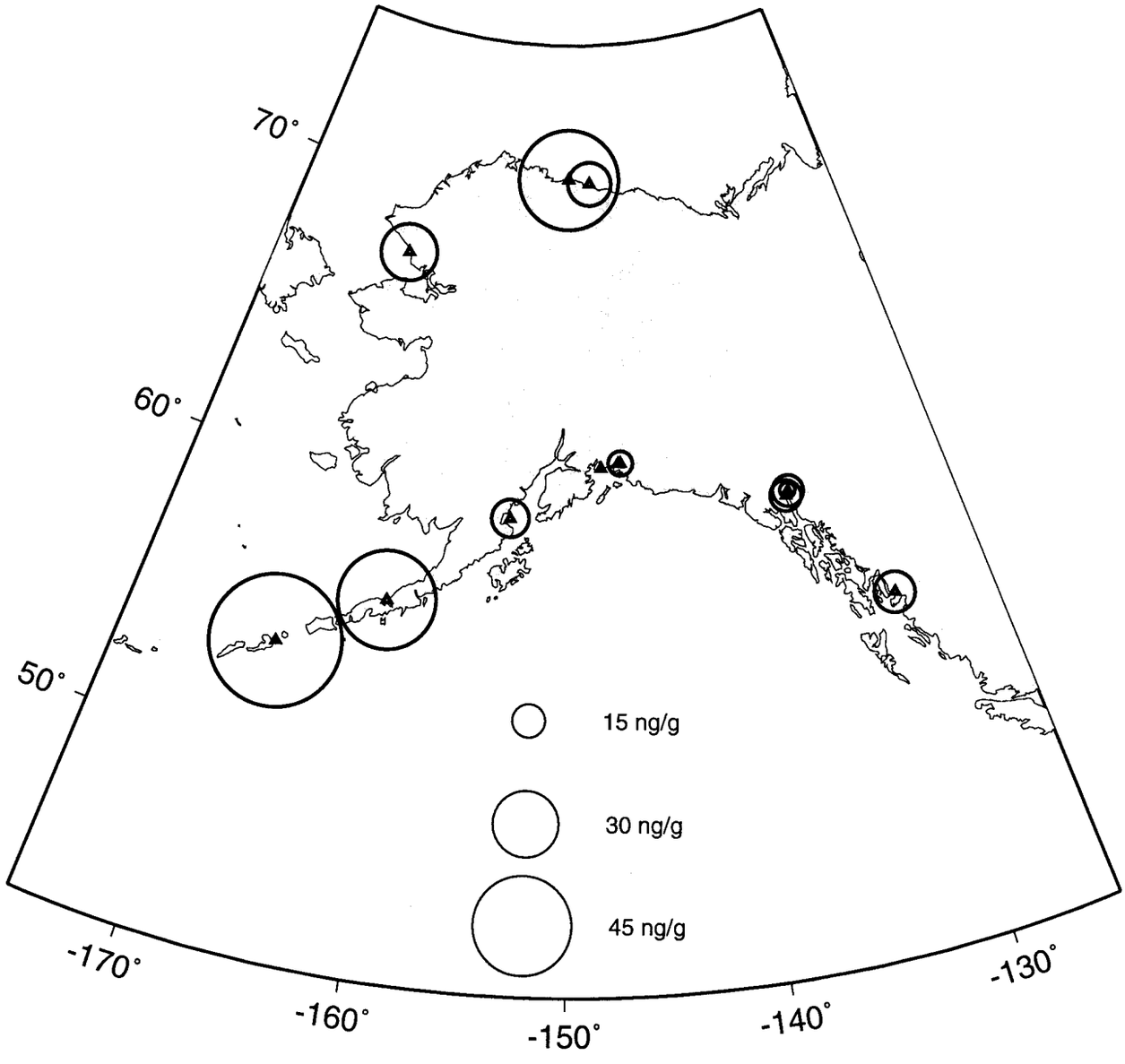
C28-NS&T Sediments: Perylene



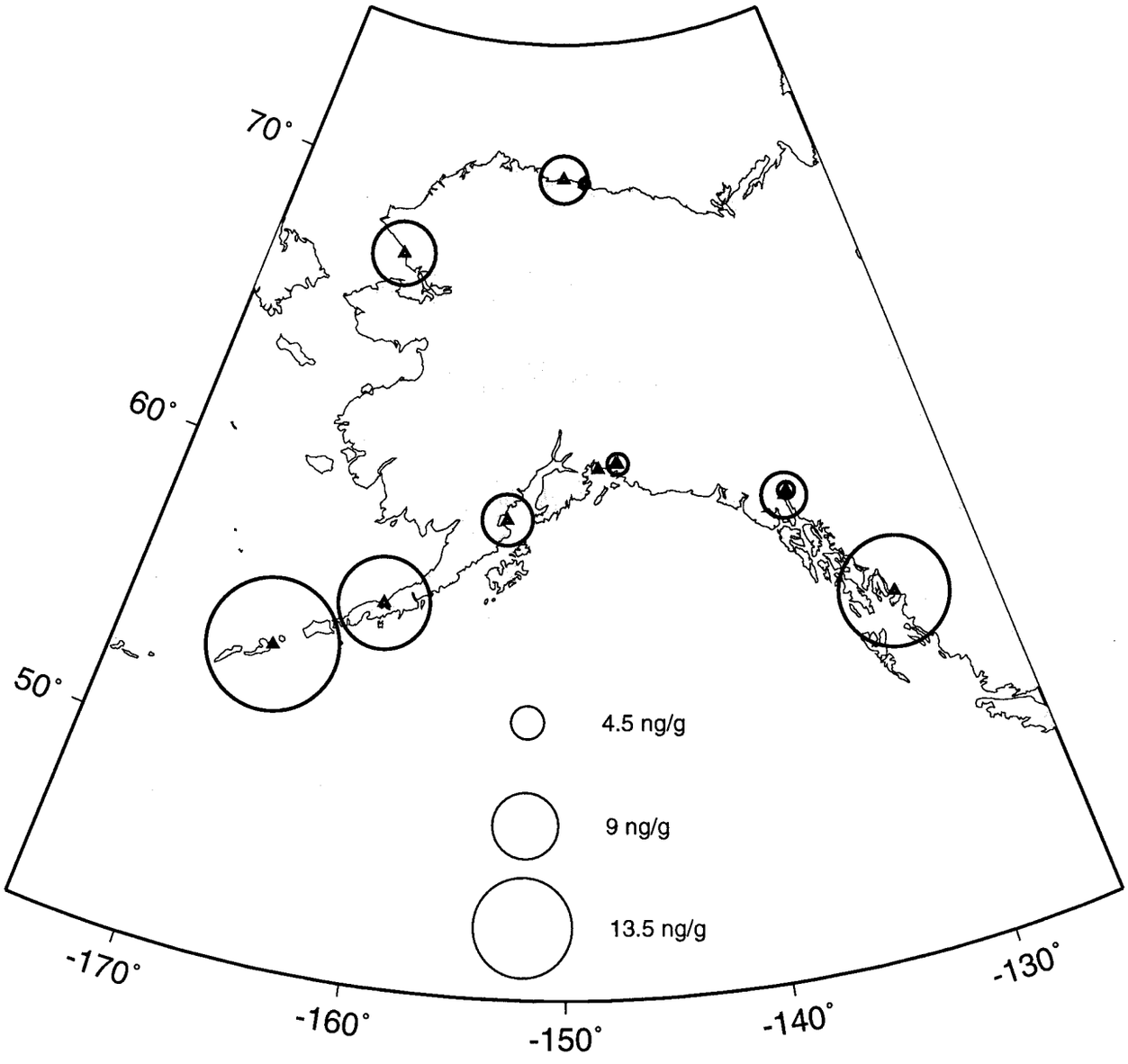
C29-NS&T Sediments: Total PAHs



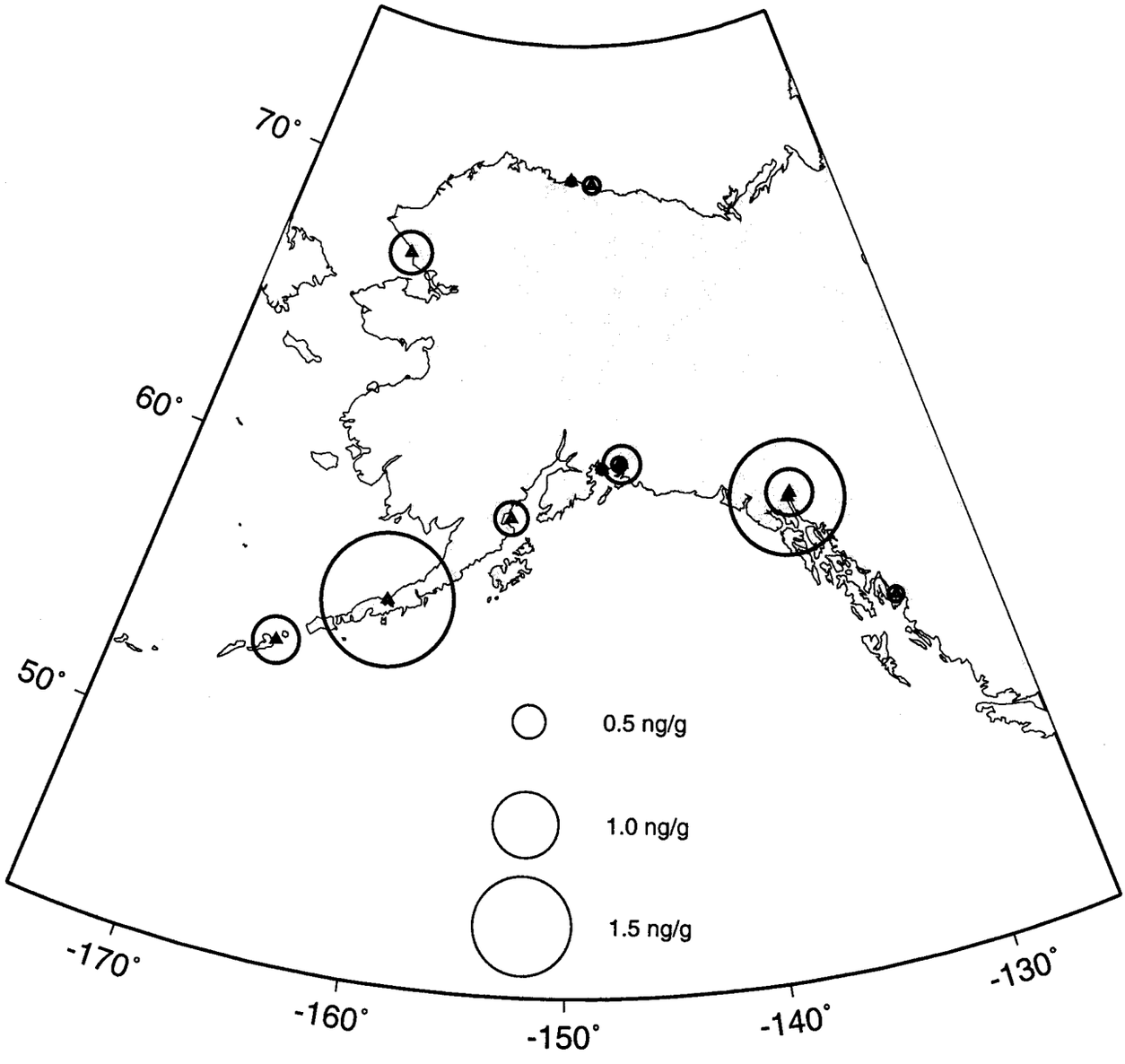
C30-NS&T Sediments: Total PCBs



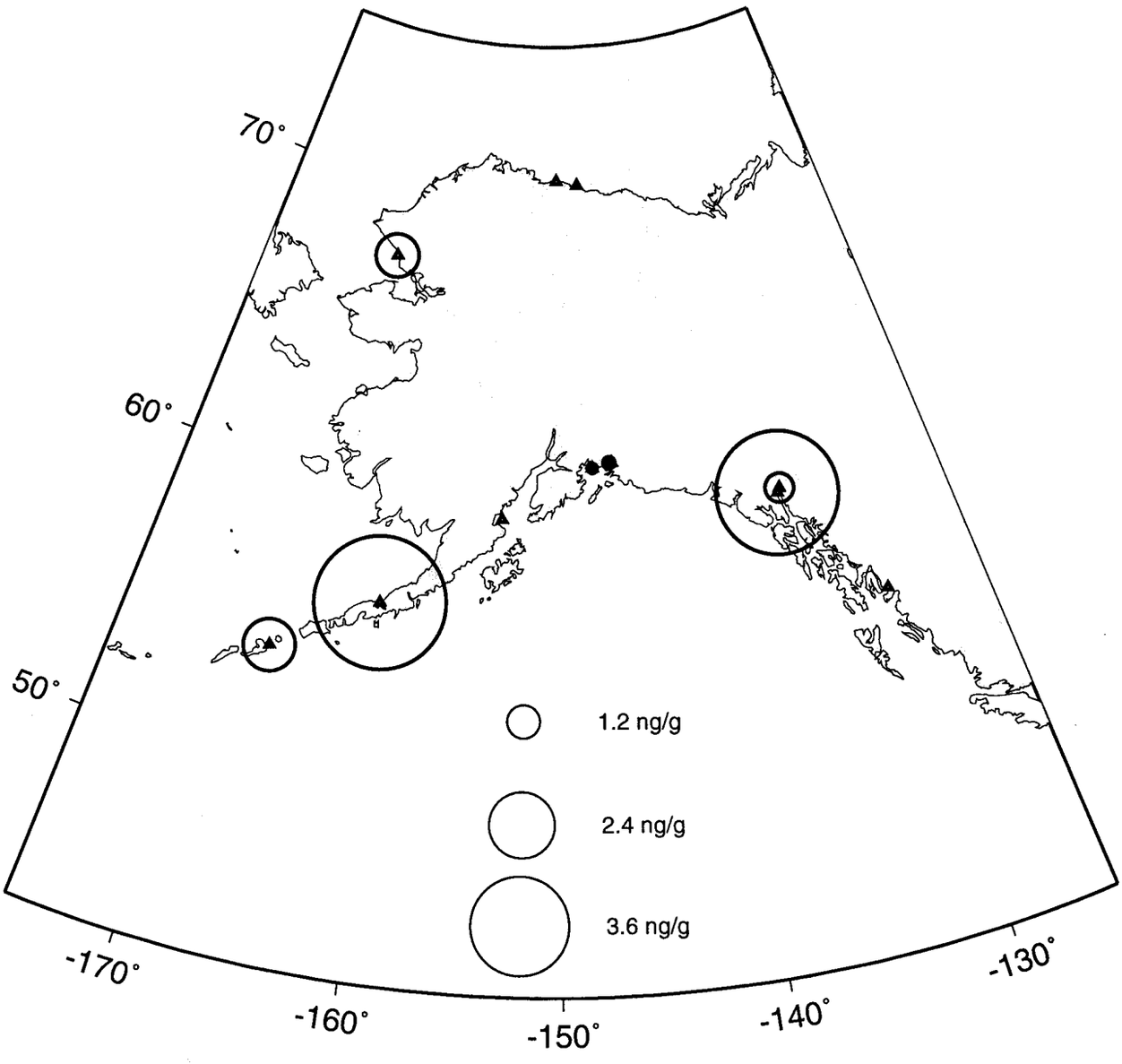
C31-NS&T Sediments: Total PCB Congeners



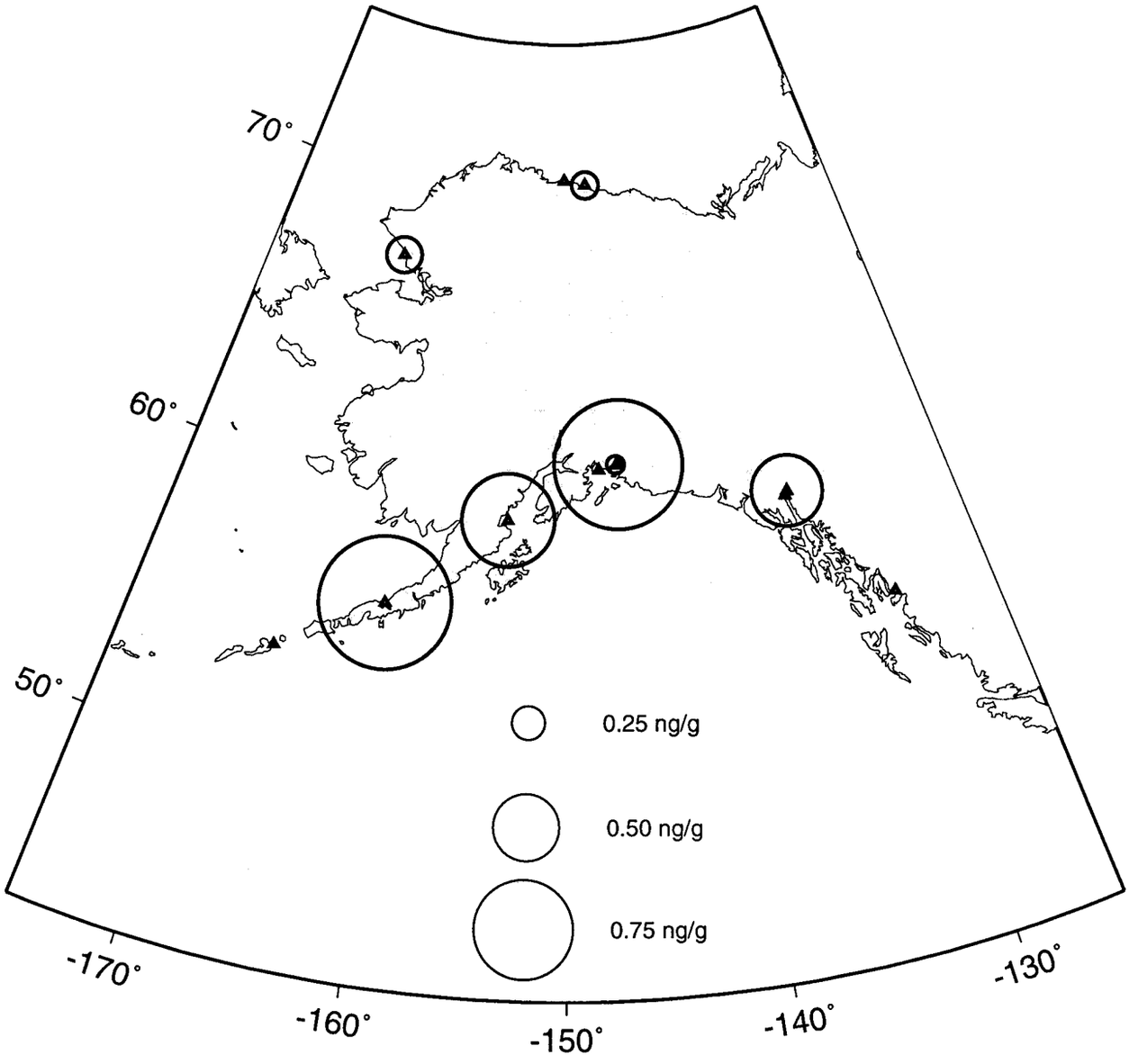
C32-NS&T Sediments: Total Pesticides



C33-NS&T Sediments: Total DDTs



C34-NS&T Sediments: Lindane



C35-NS&T Sediments: Hexachlorobenzene